City of Bellevue
Electrical Reliability Study
Phase 2 Report

Exponent®

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Phase 2 Report

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Acronyms and Abbreviations

AMI	advanced metering infrastructure
AMR	automatic meter readers
BPA	Bonneville Power Administration
CCIF	Critical Consumer Issues Forum
CIS	Customer Information System
CLX	ConsumerLinX
CPUC	California Public Utilities Commission
DMS	Distribution Management System
DNP	distributed network protocol
DOE	U.S. Department of Energy
ECC	Emergency Coordination Center
EISA	Energy Independence and Security Act
EMS	Energy Management System
EOC	Emergency Operations Center
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
GIS	geographic information system
IEEE	Institute of Electrical and Electronic Engineers
IOU	investor owned utility
IP	Internet protocol
IRP	Integrated Resource Plan
KEMA	KEMA Consulting Company
kV	kilovolt; one kV equals 1000 V
kW	kilowatt
kWh	kilowatt-hours
LBNL	Lawrence Berkeley National Laboratory
MDMS	Meter Data Management System
MVA	megavolt-ampere
MW	megawatt (1 MW equals one million watts)
NERC	North American Electric Reliability Corporation
NIMS	National Incident Management System
NIST	National Institute of Standards and Technology
NOS	network open seasons
^{o}C	degree Celsius
OMS	Outage Management System
PG&E	Pacific Gas & Electric Company
PSE	Puget Sound Energy
R&D	research and development
RCW	Revised Code of Washington
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAP	Systems Analysis and Program Development System
SCADA	Supervisory Control and Data Acquisition

SF6	sulfur hexafluoride
T&D	transmission and distribution
V	volts; a unit for voltage (electric potential)
VAC	volts alternating current
WAC	Washington Administrative Code
WECC	Western Electricity Coordinating Council
WUTC	Washington Utilities and Transportation Commission

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Executive Summary

Study Results

The City of Bellevue (the City) retained Exponent to perform an electric system reliability assessment to assist the City in meeting its goals to be an informed stakeholder and to work with Puget Sound Energy (PSE) to ensure a reliable electric power supply for the City. The study was performed to answer the following questions from the Electric Reliability Study Plan[1]:

1. *"How does PSE's existing system serving Bellevue perform relative to the Washington Utilities and Transportation Commission (WUTC) expectations, industry standards, and peers relative to reliability?"*

   There are over 90 circuits in Bellevue and while the performance on individual circuits can vary, the overall system in Bellevue is reliable.

   Electric system reliability is measured by the availability of the system to deliver electric power to a customer's meter in accordance with voltage and frequency requirements specified by the WUTC.[2] Reliability is therefore a measure of the probability that electric power is delivered in accordance with those requirements. Electric system reliability is typically measured based on the frequency (System Average Interruption Frequency Index [SAIFI]) and duration (System Average Interruption Duration Index [SAIDI]) of outages relative to the number of customers.

   WUTC has established reliability goals for its regulated utilities (service quality indices). Prior to 2010, the measures included SAIFI (frequency of outages per customer) and SAIDI (duration of outages per customer) goals for PSE of 1.3 and 136 minutes, respectively, excluding major storm events. While PSE has not always met the SAIDI goals system-wide, Bellevue's reliability has met the SAIFI and SAIDI goals over the past 5 years. In 2010, the reliability in Bellevue measured 0.44 and 66 minutes, respectively for SAIFI and SAIDI. In 2010, the measure for SAIDI was changed to include a 5-year average including major storm events and PSE met that goal system-wide. They will report this measure for Bellevue's circuits in 2011.

   PSE participates in an industry reliability survey through the Institute of Electrical and Electronics Engineers. PSE's overall system reliability performance is typically in the 1st or 2nd quartile on SAIFI (frequency of outages) and 2nd or 3rd quartile in SAIDI (duration of outages) (with the 1st quartile being best performance). PSE's 2010 performance for SAIFI and SAIDI was 0.86 and

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1 Reference 10.

2 Washington Administrative Code (WAC)480-100.

129 minutes, respectively, and as shown above, Bellevue had significantly better reliability performance.

2. *"What changes relative to facilities, equipment, planning, and emergency operations will improve electric system reliability, communication, and outage response in Bellevue?"*

   While there has been improvement in the reliability of the Bellevue system over the past several years, the following enhancements are required to ensure continued improvement in reliability for the City:

   - Hardening of the Bellevue system to ensure appropriate redundancy to all substations and circuits.
   - Continued focus on underground cable replacement and remediation as well as replacement of older switches and transformers placed in underground vaults.
   - Review of specific circuits within the City that experience lower reliability to identify improvement actions.
   - Accelerate investments in distribution automation (including a Distribution Management System [e.g., Supervisory Control and Data Acquisition]) to improve reliability and to enable future technologies.
   - Develop strategies to provide greater opportunities for undergrounding lines experiencing lower reliability due to tree and storm impacts.
   - Improvements in the information technology infrastructure for outage management and customer interface to specifically improve communication and outreach to customers during outages on the system.

3. *"Will the City have adequate and reliable power supply to meet future City growth needs?"*

   Based on current plans, the City will have an adequate and reliable power supply to meet the medium-term (5–10 years) and long-term (10–20 years and beyond) growth requirements. The current plan includes:

   - Capacity additions, including upgrade of the 115 kV lines running north-south through Bellevue.
   - Addition of transformer banks to support growth in the Downtown, Bel-Red, and Eastgate/Somerset areas.
   - Upgrade of 115 kV lines to support additional transformer banks.
   - Support of PSE plans to significantly reduce the peak electric power demand through the use of more efficient electric lighting and equipment.

4. *"What opportunities are available to the City to work with PSE, regulators (WUTC,* Federal Energy Regulatory Commission*), and other stakeholders to ensure the needs and expectations of Bellevue's residents and businesses are met relative to the reliability of the power supply?"*

   Bellevue's role as an informed stakeholder requires that the City take an active role in becoming informed on matters affecting the reliability and planning for the electric system in Bellevue. This role includes direct communication with PSE as well as other stakeholders regarding electric service. Specific opportunities for the City to engage as an active stakeholder include:

   - WUTC: The City has a role in informing lawmakers and commissioners regarding matters that affect reliability. The City also has the opportunity to comment or participate in matters directly affecting PSE and its interaction with WUTC. It may be possible for Bellevue to support measures for investment brought forward by PSE that support its overall City goals for electric system reliability and service.

   - PSE: The City has many opportunities to proactively interact with PSE on issues related to system reliability, long-term planning, near-term major project planning, Smart Grid initiatives, and emergency planning.

5. *"How can the City measure and monitor whether improvement in reliability is being achieved?"*

   This reliability assessment includes recommendations for the City to consider moving forward. Proposed reliability improvement metrics have also been included to assist the City in measuring and monitoring the implementation and effectiveness of these recommendations.

This reliability study provides the analyses and recommendations to support the City in meeting its goals to be an informed and active stakeholder and to ensure that the City has an adequate and reliable electric system now and into the future.

Recommendations Summary

The outcome of this reliability assessment is a set of recommendations that will support the City's efforts to meet its stated goals. The recommendations are summarized below:

1. **Conduct Joint City/PSE Reliability Workshops—**The City should conduct an annual reliability workshop with PSE to perform a review of the following topics that relate to reliability in Bellevue:

   - Specific Circuit Reliability: The City should request reliability metrics (SAIDI and SAIFI) on a circuit basis. This will provide the City with information regarding the performance of circuits throughout the City and provide a basis for the City to work with PSE to identify appropriate means to improve performance.

- The City should trend circuit performance over time to identify the effectiveness of completed reliability projects (review number of outages and causes to trend improvement). This assessment provides the City with a means of reviewing the overall Downtown performance and performance for specific neighborhoods that have experienced frequent outages (such as neighborhoods with overhead circuits).

- Equipment Reliability Projects: The City should request a list of the current PSE projects identified for Bellevue (both funded projects in the capital plan and those waiting future funding) to understand the potential reliability improvement efforts for Bellevue.

- Maintenance and Inspection Program Results: PSE should identify to the City any new items likely to significantly affect the electric system reliability from its review of maintenance and inspection programs during the prior year.

- System Redundancy Projects: The City should review the design improvements that are being added to the Bellevue system.

- Automation Installation: The City should review with PSE the automation improvements that are being added in the Bellevue system. The City can monitor the overall upgrades to the system and the degree of system automation.

2. **Joint City/PSE Planning Workshops—**It is recommended that the City engage PSE in an annual planning workshop around future projects. The Comprehensive Plan includes an electric system plan that can serve as the basis for the annual workshop. The workshop should focus on the following items:

   - Current growth projections and electric power use in Bellevue

   - Review and update of current plan

   - Actions for capacity projects required to initiate siting and permitting activities within the next 2 years.

   An outcome of the workshop should be an updated plan for inclusion in the Comprehensive Plan (if required) and an action plan to move designated projects forward into siting analysis and/or planning.

3. **Integrated Resource Planning (IRP)—**The City should remain active in the IRP process and should begin to understand potential long-term impacts of this strategy.

4. **Vegetation Management—**The visual review of overhead circuits indicates that there are many substations and lines located in heavily wooded areas. The only way to significantly improve reliability is to perform more comprehensive tree

trimming. The City should review its vegetation policies, specifically in the areas of substations, to look at alternative vegetation approaches.

5. **Community Communications—**City personnel involved in emergency response should meet with PSE to understand the capabilities of the new outage management system (when completed) to assist in communications with the Bellevue community.

6. **Emergency Response Capability—**The City and PSE should consider the development of a more formal process (procedure) related to response and support activities during an outage. The outcome should be an agreement (or procedure) for communication and coordination during large-scale events affecting Bellevue.

7. **Energy Efficiency Improvements—**The City should lead the energy efficiency effort to assist PSE in reaching its long-term electric energy usage goals to help ensure adequate electric power supply during peak power periods for the City. Electric energy savings programs require active outreach to the customers and citizens to support various efficiency initiatives. The PSE long-term plan has a large reliance on reducing the electric energy demand by installing lower power consuming appliances and lighting systems. The City will have a major role to play in terms of City policy and regulations that support efforts that are alternatives to building additional power plants to supply peak power during high demand periods. The City will also have a major role in community outreach.

8. **Undergrounding of Distribution Lines—**The City should investigate opportunities for additional undergrounding of distribution lines through coordination of multiple utility projects and evaluation of local improvement districts. The City's Comprehensive Plan requires undergrounding of new distribution lines and strategies should be developed to increase opportunities to convert overhead lines to underground circuits.

9. **City Interface with WUTC—**Bellevue's involvement with WUTC should be one of informing lawmakers and commissioners regarding matters that affect reliability. This involvement should include:

    - Assigning a designated individual to electric system matters. This individual should remain informed of electric system activities related to WUTC.
    - Developing "white papers" for submittal to WUTC to inform the Commission of issues affecting electric reliability in the City. This provides a means to provide feedback to WUTC without direct response to hearings.
    - Commenting on or participating in matters directly affecting PSE and their interaction with the WUTC.

There are several additional recommendations that can be incorporated into the recommendations listed above. These include:

10. **Smart Grid Strategies—**PSE has identified a series of Smart Grid technology projects that are being considered over the next 2 years. These projects include a range of programs from the base infrastructure required to enable the Smart Grid to specific customer-related efforts. The City should review the overall PSE plan and determine its level of support for the various customer initiatives. The City needs to define a Smart Grid approach that it would like to see implemented in Bellevue, specifically addressing the level of support for customer interface applications, such as customer energy management, demand response, home automation, etc. The City should work with PSE to develop a Bellevue deployment plan consistent with PSE obligations. (Include with Recommendation #1)

11. **Long-Range Planning—**The City and PSE should synchronize their growth projections for the City by frequent information exchange on expected projects, expected timing of projects, and coordination of actions required by PSE and the City to address these projects. This exchange is meant to assist longer-term planning and should occur well in advance of any specific permitting or development activities. (Include with Recommendation #2)

12. **Multi-Utility Planning—**The City should engage with its utility partners to identify new projects (both large and small) to maximize efficiency for projects in the rights-of-way. The City can take advantage of projects that require trenching to place conduit for potential future use of undergrounding. The existence of conduit may allow for more economic alternatives for undergrounding in the future. (Include with Recommendation #1)

Detailed descriptions of these recommendations are included in this report.

Conclusions

This assessment of the electric system serving the City has shown that electric system reliability is improving and that the programs and projects shown in PSE's planning documents should continue to improve system reliability. However, successful execution of plans, programs, and projects is required to ensure that there is an adequate and reliable electric power system serving the City.

The recommendations offered for consideration by the City are intended to provide a basis for the City to become an informed and active stakeholder relative to decisions and actions required to support continued and improved electric system reliability.

1 Introduction

1.1 Background

The City of Bellevue (the City) retained Exponent to perform an electric system reliability assessment to assist the City in meeting its goal to be an informed stakeholder to ensure a reliable electric power supply for the City. The scope of the study is to answer the following questions from the Electric Reliability Study Plan[3]:

1. **Current System Assessment:** Define good industry practices for electric service providers in areas such as system planning, operations, maintenance, and new technologies to compare against the current state of the electric system in the City of Bellevue; and identify areas of improvement to increase reliability, system modernization, innovation, and capacity. This task will answer questions such as:

    a. "How does Puget Sound Energy's (PSE's) existing system serving Bellevue perform relative to the Washington Utilities and Transportation Commission's (WUTC's) expectations, industry standards, and peers relative to reliability?"

    b. "What changes relative to facilities, equipment, planning, and emergency operations will improve electric system reliability, communication, and outage response in Bellevue?"

2. **Future System Study:** Assess PSE's long-term electric system plan to serve the City of Bellevue to identify opportunities to increase system reliability, system modernization, innovation, and capacity. This task will address the question of "will the City have an adequate and reliable power supply to meet future City growth needs?"

3. **Role of the City:** Define the role of the City relative to its interaction with PSE, the electric system owner, and associated regulatory agencies, such as WUTC, the Federal Energy Regulatory Commission (FERC), and the Western Electricity Coordinating Council (WECC) to ensure a highly reliable electric system for the City of Bellevue and to increase confidence in electric system reliability. This task will address the concern of "what opportunities are available to the City to work with PSE, regulators (WUTC, FERC), and other stakeholders to ensure Bellevue residents' and businesses' needs and expectations are met relative to the reliability of the power supply?"

[3] Reference 10.

4. **Measurement and Monitoring:** Define the criteria for the City to measure and monitor the performance of the electric power system serving its residents and businesses to ensure continuous reliability and planning improvement. This task addresses the issue of "how can the City measure and monitor whether improvement in reliability is being achieved?"

This study was performed in two phases. During the first phase, Phase 1, Exponent prepared an Electric Reliability Study Plan[4] that outlined the scope of work for Phase 2 of the electric reliability study. The Phase 1 effort defined the scope of the reliability study to answer the questions above and to achieve the City's objectives defined below:

- Enhance the City's role as an informed stakeholder
- Ensure that an adequate and highly reliable electric system is built, operated, and maintained
- Ensure that the electric system keeps pace with future load growth
- Enhance the relationship between the City and PSE
- Ensure fair and reasonable rates
- Improve PSE transparency of operation.[5]

The Phase 1 scope was based on an initial review of the PSE electric system in Bellevue and feedback received from the Bellevue stakeholders.

1.2 Scope of Work

The planning horizon for this study covers the time period between 2010 and 2030 (the projected time frame for build-out of the Downtown). The reliability study was performed in four tasks:

1. **Current System Study:** The current system study reviewed current electric system performance including:
   - Review of PSE reliability metrics and how they compare to industry performance
   - Assessment of PSE outage data to identify current issues (equipment and event causes) affecting reliability in the City
   - Assessment of system and equipment design relative to distribution, transmission, and generation assets and their impact on reliability

4 Reference 10.

5 Reference 1.

   - Assessment of PSE work processes for the key activities affecting reliability including maintenance, capital project prioritization, and outage management
   - Identification of industry practice and benchmarks related to the above areas of review.

2. **Future System Study:** The future system study reviewed the activities related to growth and reliability affecting the City including:
   - Short-term issues related to current capital investments, planning, Smart Grid deployment, outage management, and other operating systems
   - Medium-term issues related to growth and reliability of the generation, transmission, and distribution assets
   - Long-term issues related to growth and reliability including build-out of the City for its generation, transmission, and distribution assets.

3. **Role of the City:** The role of the City is defined relative to:
   - Its interactions with its stakeholders and industry participants, including WUTC, PSE, and other stakeholders
   - Transparency of electric system operations in the City.

4. **Measurement and Monitoring:** This task provides the plan to measure and monitor the implementation of the recommendations provided in the previous tasks.

Table 1 shows how the four tasks in the reliability study address the City's objectives. Exponent's scope did not include a review of the rate structure for the objective related to "ensure fair and reasonable rates."

The study was prepared from the perspective of the City and its role as a key stakeholder in working with PSE to ensure reliable electric supply for Bellevue residents and businesses. Therefore, the assessment is primarily focused on reviewing and evaluating the current and future status of the distribution system in Bellevue. However, some aspects of reliability require an assessment of the overall capability to deliver power to Bellevue. Where appropriate, therefore, assessments of the transmission and generation systems were performed to determine their impact on reliability in Bellevue.

The results of the study are provided in the Sections 2 through 5. The following appendices are presented at the end of the main text:

- Appendix A—*References*
- Appendix B—*Electric Reliability Basics*

- Appendix C—*Outage and Equipment Codes*
- Appendix D—*List of Documents Reviewed*
- Appendix E—*Circuit Reliability Analysis*
- Appendix F—*Reliability Projects in Bellevue*
- Appendix G—*Phase 1 vs. Phase 2 Roadmap*
- Appendix H—*Response to Questions*

Table 1. Reliability Study vs. Bellevue Goals

	Task			
City Objective	Task 1: Current System Assessment	Task 2: Future System Assessment	Task 3: Role of the City	Task 4: Measurement and Monitoring
Enhance City's role as informed stakeholder	X	X	X	X
Ensure that a highly-reliable electric system is built, operated, and maintained	X	X		
Ensure that the electric system keeps pace with future load growth	X	X		
Enhance the relationship between the City and PSE	X	X	X	X
Ensure fair and reasonable rates			X	
Improve PSE transparency of operation	X	X	X	X

1.3 Reliability Vision for Bellevue

Bellevue's goal is to have a highly reliable electric system that maintains good service to its current community and attracts new businesses and members to the community in the future.

A reliable system today for Bellevue could include the following elements:

- A redundant system in the Downtown area and other densely populated areas that is capable of surviving two independent fault events without an outage (N-2 contingency).
- A redundant system in the neighborhoods of the City that is capable of sustaining an outage with one circuit out of service (N-1-1 contingency) with back-up ties to other feeders.
- A robust system that can minimize damage from storms and external events.
- Equipment replacement, inspection, and maintenance programs that utilize current technology to enable a robust system that minimizes equipment failures.

- Extensive use of distribution automation and distribution management to provide visibility into the state of the system and to allow for fast recovery when an outage occurs.
- Installation of a communications backbone that enables the use of new technologies, including Smart Grid technologies, in the future.
- Effective outage and emergency management programs that provide timely and frequent communication to customers.

This vision of reliability is the basis for providing recommendations that the City can use to become an active participant in ensuring reliable service to the City. To achieve this level of reliability requires capital investments that could increase the cost of power delivered to Bellevue. In addition, many of the investments must be made by PSE across its entire service area. Therefore, this vision must be tempered and balanced to avoid increasing the cost of power to Bellevue and PSE's customers. Consequently, the investments have to be made over time. This vision of reliability is the basis for providing recommendations that the City can use to become an informed stakeholder.

The current Bellevue system contains many elements of this vision and has plans to move in this direction. This report will indicate where the City stands relative to this definition of reliability and what activities the City can undertake to work with PSE to obtain this vision.

In its Comprehensive Plan, the City outline goals for planning, permitting, undergrounding of new lines, multiple uses of sites, and joint utility operations that are consistent with its vision of a reliable system.

The future system must accommodate two major needs: capacity additions and cost-effective investments in new technology. The system must:

- Maintain its redundant nature even as capacity expansion occurs.
- Make use of distribution automation and communication infrastructure that will enable various new technologies and allow PSE to operate more efficiently, and to facilitate distributed generation, demand management, and customer Energy Management Systems (EMSs).
- Increase visibility into the electric system for all customers, which should increase the customer satisfaction level.
- Contain electric efficiency that will minimize utility needs for peaking capacities if this is a cost effective use of resources.
- Accommodate significant power supply from renewable generation sources to meet regulatory demands.

This report focuses its recommendations on areas for the City to engage with PSE in order to ensure reliable service.

2 Current System Study

2.1 Study

2.1.1 Study Scope

The current system study was performed to assess the current electric system reliability in Bellevue. The study addresses the following questions:

- "How does PSE's existing system serving Bellevue perform relative to WUTC expectations, industry standards, and peers relative to reliability?"
- "What changes relative to facilities, equipment, planning, and emergency operations will improve electric system reliability, communication, and outage response in Bellevue?"

2.1.2 Reliability Definition

Power system reliability encompasses the time an electric system is available to deliver electric power to a customer's meter in accordance with voltage and frequency requirements specified by PSE's agreement with WUTC. [6] Reliability is therefore a measure of the probability that electric power is delivered in accordance with requirements. Reliability measures include frequency of interruptions, time between interruptions, duration of restoration, and number of end-users affected. Momentary power system disturbances with a duration from a fraction of a cycle to several cycles are not included in this review because the electrical equipment should be designed to ride through many such disturbances. [7]

Today, reliability is typically measured based on the frequency and duration of outages relative to the number of customers. There are several measures for reporting and measuring electric reliability, such as the Institute of Electrical and Electronics Engineers (IEEE) Standard definitions[8] or similar approaches to report reliability. These measures include SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). See Appendix B for further information about how these numbers are calculated.

For the current system assessment, a highly reliable system is one that has redundancy in the power system design; equipment that is designed, operated, and maintained to minimize the probability of failure; sufficient automation to identify faults and their locations and to support

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[6] See WAC Sections 480-100-368 and 480-100-373.

[7] See http://www.itic.org/clientuploads/Oct2000Curve.pdf for detailed information about momentary voltage interruptions, sags, and swells. The performance limits defined in this document are applicable to information technology equipment.

[8] Reference 11.

minimizing outage recovery time; and provisions for effective communication between all stakeholders.

2.1.3 Study Approach

The current system assessment was performed in the following steps:

- Assessment of past and current reliability performance as measured by industry standard reliability metrics to determine current PSE performance and evaluation of outage data to determine major causes of outages in Bellevue to identify potential actions to improve reliability. This evaluation included a review of overall Bellevue performance and a review of representative circuits in the City, and is intended to identify current issues affecting reliability in Bellevue.
- Review of system and equipment design to determine system strengths and weaknesses to support reliability in the City and to identify potential improvement actions.
- Review of work processes that support system reliability to identify areas of improvement. These work processes include maintenance, capital project prioritization, vegetation management, and outage management.

The overall result of the current system study provided a set of observations and findings that led to identified actions for reliability improvement and to recommendations that the City can take to ensure a reliable system. This section is focused on the status of the current system and provides the basis for near-term observations and recommendations, which will be presented for each of the subtasks below. A longer-term assessment of the system in the City for future growth needs is discussed in Section 3.

2.2 PSE's Past and Present Reliability and Outage Performance

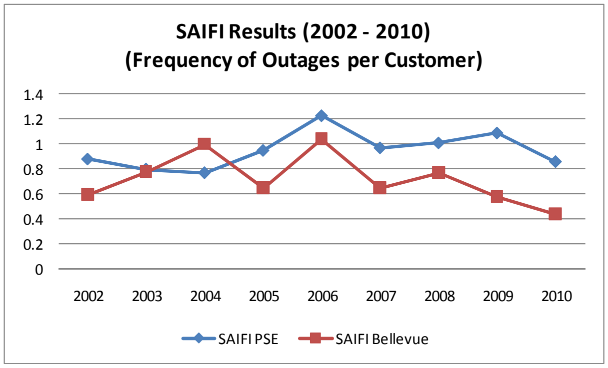
2.2.1 Study Approach

Electric service is provided to Bellevue by PSE, a regulated utility under the auspices of the WUTC. PSE provides electric service in Washington State to approximately 1.2 million electric customers and Bellevue represents roughly 10% of PSE's customer base. PSE provides annual reliability reports to WUTC and also provides Bellevue with an annual reliability report specifically for the City. Therefore, the available data facilitates a comparison between PSE's overall system performance as well as Bellevue-specific performance data. Thus, this section provides a review of PSE's overall system reliability based on reported reliability metrics (the SAIDI and SAIFI outage statistical data) and an analysis of specific outage causes in the City to determine issues affecting reliability.

2.2.2 Analysis

2.2.2.1 Reported Reliability Performance

The overall reliability performance in the PSE territory as well as the performance in Bellevue is shown in Figure 1 below:



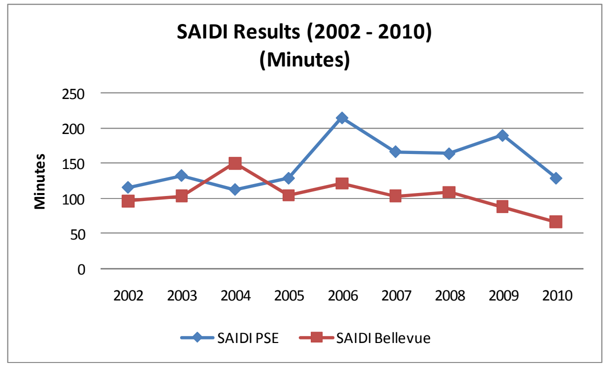


Figure 1. PSE System and Bellevue SAIFI and SAIDI Results[9]

The focus of the assessment has been on performance over the past 5 years after the major storm in 2006. At the request of the Stakeholder Committee, data has been included in the graphs covering the last 9 years but no detailed analysis has been performed on the failure causes and trends for more than the past 5 years since the massive restoration efforts after the 2006 storm should have changed the average equipment population age, making trend analysis difficult to interpret.

The reliability metrics reported include only non-major (storm) outages, where a major outage is defined as an outage that affects greater than 5% of the customers. Based on this definition, the overall reliability within PSE's territory shows improvement over that past 5 years.

The performance in Bellevue is better than that of PSE's total service area, which has also shown improvement during this 5-year period. These results for Bellevue compared with the rest of the PSE territory are expected since Bellevue represents one of the densest parts of PSE's service territory. Typically, these urban areas have the most built-in system redundancy, which makes it possible for the electric power system to lose one or more components without causing service interruptions to most if not all of the connected power users. Therefore, they may experience fewer outages and shorter recovery times. Additionally, faster recovery is due to the proximity of the urban areas to service centers where material and personnel are available for the restoration efforts.

There are several benchmarks that can be used to assess overall PSE performance, including the following:

- WUTC has established goals for its regulated utilities (service quality indices) and several of these goals relate to electric system reliability. Prior

9 References 2 and 5–8.

to 2010, the measures included SAIFI and SAIDI goals for PSE of 1.3 and 136 minutes, respectively. PSE has achieved the SAIFI goals over the past 5 years, but has not achieved the SAIDI goals, except in 2010. In 2010, the WUTC measures changed to a SAIDI based on a 5-year average including all customer outage minutes. The current goals are 1.3 and 320 minutes, respectively. PSE achieved both goals in 2010.

- With respect to the performance in Bellevue, the reliability measures are well below PSE's system-wide averages for the time period 2006–2010 and have experienced significant improvement during the time period. Some reasons for the improved performance over the past 5 years are presented later in this section.

While these measures represent overall performance at a high level, they do not highlight specific issues. The key is to understand the bases behind these reliability statistics. The discussion that follows provides an analysis of the past 5 years of outage events in Bellevue to determine the main causes of outages and to evaluate the actions that may mitigate these events.

2.2.3 Analysis of the Outage Statistics

The outage assessment was conducted by performing an analysis of available outage data to identify the main causes of outages in the City to provide a basis for developing recommendations for improvement. The outages experienced by Bellevue are defined in the annual PSE Reliability Reports[10] prepared for the City. The reliability information included in the annual reports includes a listing of each outage as follows:

- Circuit identification
- Identified cause
- Equipment type affected
- Non-storm or storm event.

2.2.3.1 Outage Data Information Content

The reliability and outage information for Bellevue shows the overall annual outage trends and outage causes for the entire City. The outage data shown in the following graphs includes both non-major storm events and major storm events. The non-major storm events show the outage performance for all power users in the City but the major storm events only show the system performance during events that affect a large number of customers (> 5% of the power users). Storm events tend to drive outages produced by equipment failure related to effects of water, ice, and snow damage, and more significantly by wind-driven impacts that produce failures from tree damage. The environment in the City is vulnerable to wind-driven storm damage on its overhead system. Outage data are also included for the 2006 storm.

[10] References 2 and 5–8.

2.2.3.2 Overall Bellevue Outage Trends

The annual outage trends for the past 5 years are provided in Figure 2.[11]

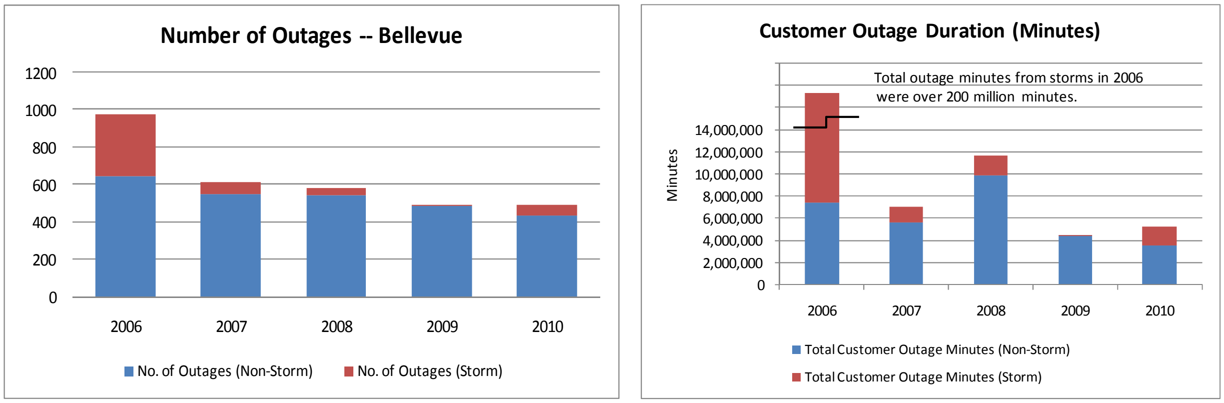


Figure 2. Outage Data in Bellevue–Number of Outages and Total Customer Duration[12]

The overall trends show an improvement in number of outages and in outage duration. A few observations on the non-major storm outages:

- During 2008, there were several major circuit outages that required significant time to restore. These few events contributed a large amount to the outage durations. These events are included in the data above, but are highlighted due to their significant contribution to the outage duration.
  - SOM-16: There was a major circuit outage that resulted from a failed underground transformer that caused over 1.4 million outage minutes.
  - COL-26: There was a major circuit outage caused by an underground cable failure that resulted in an outage of over 600,000 minutes.
  - There were five other events that produced outages of greater than 300,000 customer minutes.

Despite the performance in 2008, the overall trend (of non-major event outages) shows a pattern of improvement in the City.

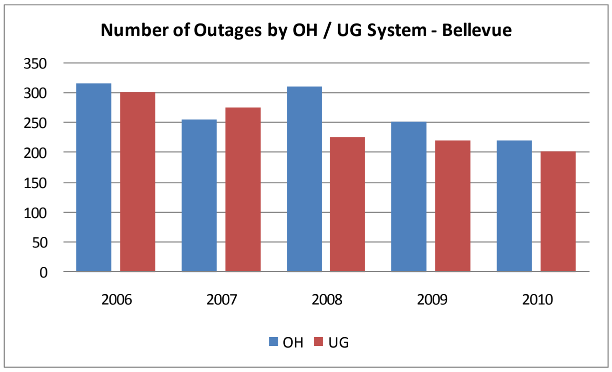
While there has been no event comparable to the 2006 storm, major storms have contributed to the outage durations in 3 of the past 4 years. As stated previously, these major storm outages are being measured and reported in the reported reliability data moving forward.

[11] The first figure shows the number of outage events and the second figure shows the duration (in minutes) of customer outages. This convention will be used throughout this section.

[12] References 2, 5–8, and 30.

2.2.3.3 Overhead vs. Underground Performance Data

Segregation of the outage information into overhead (OH) and underground (UG) systems is also of interest since the perception is that underground systems are more reliable than overhead systems. This is illustrated in Figure 3 below, which shows the impacts of outages associated with underground and overhead system. [Note: This information is based on non-major events only. However, it can be generally assumed that major storm outages will add to the overhead outages and durations.] There are roughly an even number of overhead and underground outages; however, there is a significant difference in outage duration with underground outages producing more outage minutes.



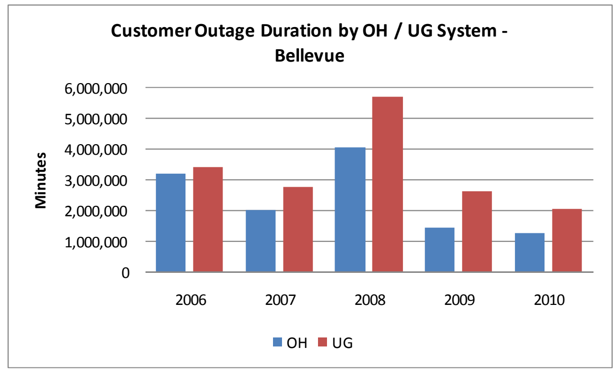
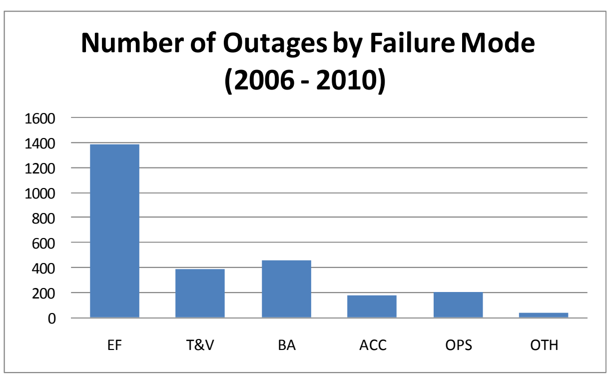


Figure 3. Outage Data in Bellevue by OH/UG Systems for Number of and Total Customer Duration[13]

2.2.3.4 Information by Type of Outage

Figure 4 provides a look at outages by cause over the past 5 years, based on number of outages and overall duration of outages. [Note: This information is based on non-major events only. However, it can be generally assumed that major storm outages will add to and increase the impact of tree-related events.]



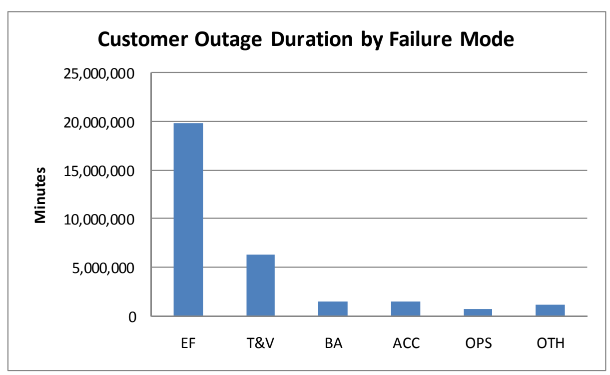


Figure 4. Outage Data in Bellevue by Failure Type for Number of Outages and Total Customer Duration[14]

[13] References 2 and 5–8.

[14] References 2 and 5–8.

The PSE reports utilize approximately 16 outage type codes. However, for purposes of this assessment, the outage codes have been enveloped into six major categories:

- Equipment failure (EF)
- Trees and vegetation (T&V),
- Bird and animal (BA)
- External accidents (ACC)
- Operations (OPS)
- Other (OTH).

The other category includes items such as installation and manufacturer issues. A list of the all the outage types is provided in Appendix C.

This higher-level view of outage types indicates that there are three primary contributors to outage events in Bellevue. Equipment failure produces the greatest number of outage events and has the greatest impact on duration, followed by tree-related and wildlife-related events. A more detailed look at the three main categories of outages provides additional insight.

2.2.3.5 Equipment Failure Outage Events

Equipment failures are identified as the most significant cause of outages in the City. Figure 5 provides the annual outage trends for equipment failure-related events.

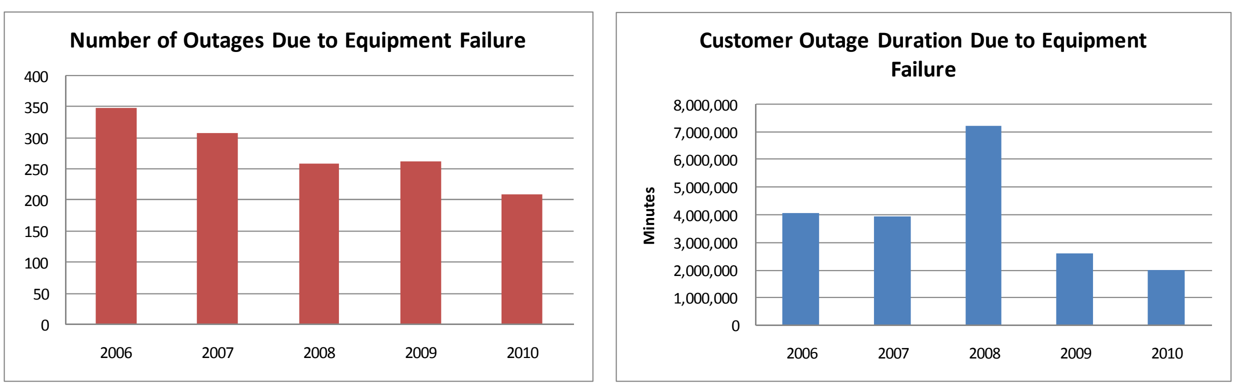


Figure 5. Outage Data in Bellevue Due to Equipment Failure for Number of Outages and Total Customer Duration[15]

The number of equipment failure-related outages has trended downward over the past 5 years, showing an overall improvement in number of outage events of approximately 40%. The reduction in total outage duration minutes due to these events has been reduced by 50%, from

[15] References 2 and 5–8.

2006 to 2010. The duration of outages in 2008 shows a significant large spike upward. This spike does not correlate to the continued reduction in number of outage events. The causes of this spike were several significant circuit events that affected a large number of customers for a significant time period. This shows that the outage duration depends on where in the system a piece of equipment fails.

2.2.3.6 Overhead vs. Underground Equipment Failures

Equipment failure-related outages can be based on overhead (OH) and underground (UG) events. Figure 6 shows the breakdown in outage events resulting from this differentiation.

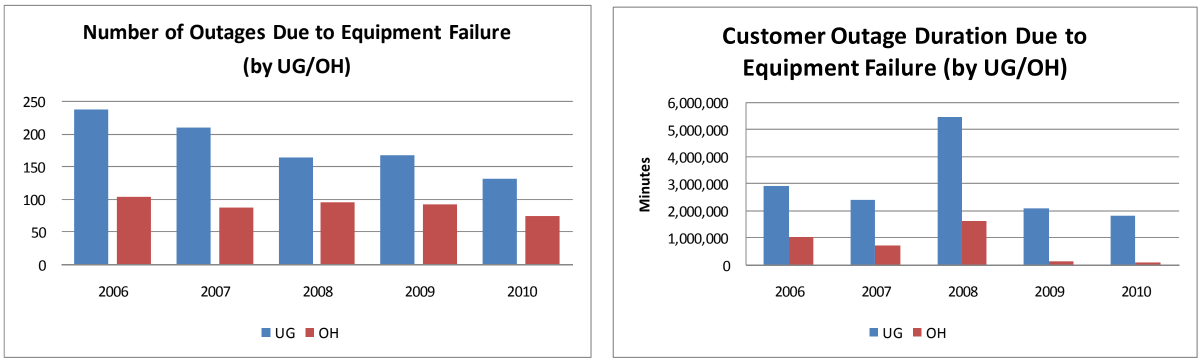


Figure 6. Outage Equipment Failure by UG/OH for Number of Outages and Total Customer Duration

The equipment failure trends for outages show that underground events are the more common in terms of number events, as well as duration. However, there has been a significant reduction in the number and duration of underground events except for 2008, which was described previously. The reduction in the number of overhead events has been slower but the duration of these events has been reduced. A further review of the equipment-failure outages is shown based on the type of equipment attributed to the event. Figure 7 shows a breakdown over the 5-year period of outage by equipment type for overhead-related events and Figure 8 shows a breakdown for underground events.

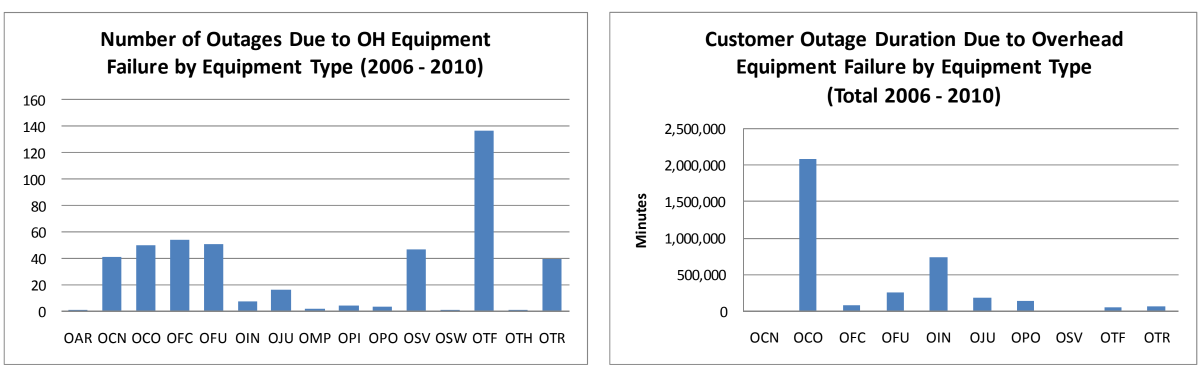
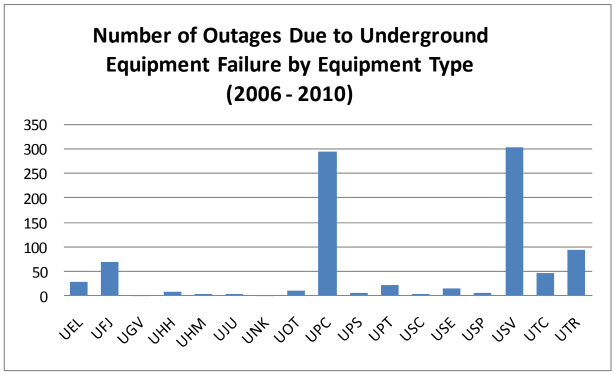


Figure 7. Underground Outages (2006–2010) in Bellevue Due to Equipment Failure by Equipment Type for Number of Outages and Total Customer Duration[16]

[16] References 2 and 5–8.



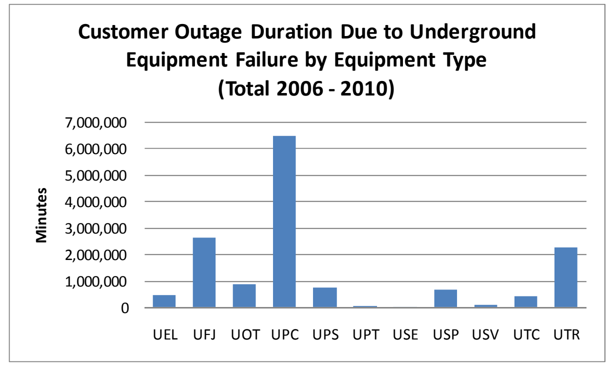


Figure 8. Underground Outages (2006–2010) in Bellevue Due to Equipment Failure by Equipment Type for Number of Outages and Total Customer Duration[17]

The major causes of overhead equipment failures are:

- Overhead transformer fuses (OTF)
- Overhead cut-outs (OFC)
- Overhead line fuses (OFU)
- Overhead conductors (OCO)
- Overhead services (OSV)
- Overhead connectors (OCN)
- Overhead transformers (OTR).

These equipment types account for approximately 90% of all overhead equipment failures with a majority of the failures associated with fuse operations (OTF and OFU). From a duration perspective, the overhead conductor (OCO) and overhead insulator (OIN) pieces of equipment account for the majority of the duration.

The number of events related to multiple types of equipment failures is mostly driven by distribution line equipment being designated as "run-to-failure." The majority of events are related to line equipment. Specific items (excluding conductors) are easily identified, replaced or repaired, and restored. Therefore, when an outage occurs, it is quickly handled by service personnel. Conductor failures, however, require more time to locate where the fault occurred and may also require more work to repair or replace. Therefore, conductor failures drive outage duration in Bellevue.

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[17] References 2 and 5–8.

There are limited outages in Bellevue caused by substation equipment failures, where it is technically feasible to perform diagnostic tests on the equipment, which often can be used to prevent failures.

The major causes of underground equipment failures are:

- Underground services (USV)
- Underground primary cable (UPC).

These equipment types account for approximately 66% of all underground equipment failures. From a duration perspective, the underground primary cable (UPC), underground J-box (UFJ), and underground submersible transformer (UTR) equipment account for about 75% of the duration.

Underground cables in Bellevue were some of the first cables installed in PSE's system. The underground cables can be either directly buried cables or cables installed in conduits. The directly buried types of cables are more prone to being affected by environmental factors including damage from soil excavation and corrosion. Underground cable degrades over time due to stresses related to the applied voltage as well as the heating produced by the load currents. Since an outage produced on the underground system is difficult to locate and requires time to access and repair, these events are significant contributors to outage durations.

2.2.3.7 Tree and Vegetation Related Outage Events

Tree and vegetation related failures are identified as a significant cause of outages in the City. From a practical perspective, tree-related events are the primary contributor to these types of outages. Figure 9 provides the annual outage trends for tree failure-related events.

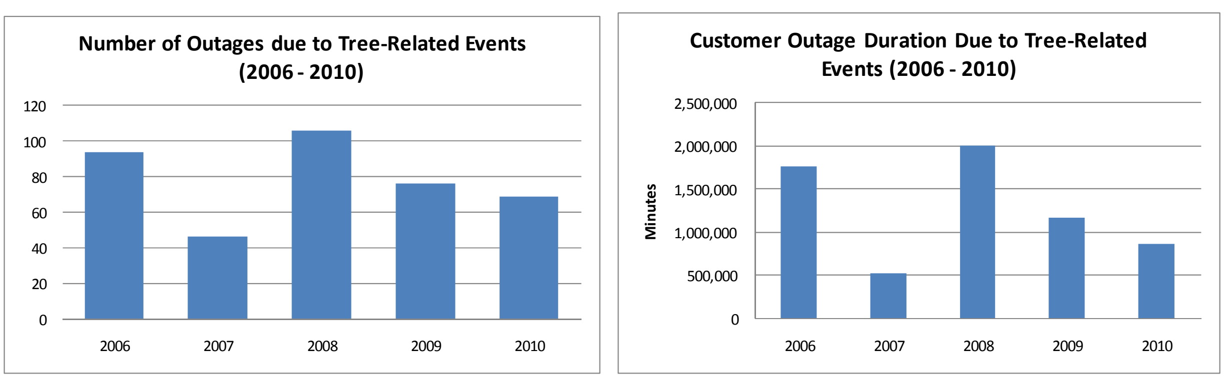


Figure 9. Outage Data in Bellevue Due to Tree-Related Events for Number of Outages and Total Customer Duration[18]

[18] References 2 and 5–8.

The number of tree-related outages appears to have trended downward slightly over the past 5-years. The outage duration appears to be well correlated with the outage frequency data. While these data are based on non-major events, major storms drive significant tree-related events. As shown previously in Figure 2, the impact of storms related events will drive the number and duration of these tree-related events higher.

Tree-related outages were caused by the following affected equipment as shown in Figure 10.

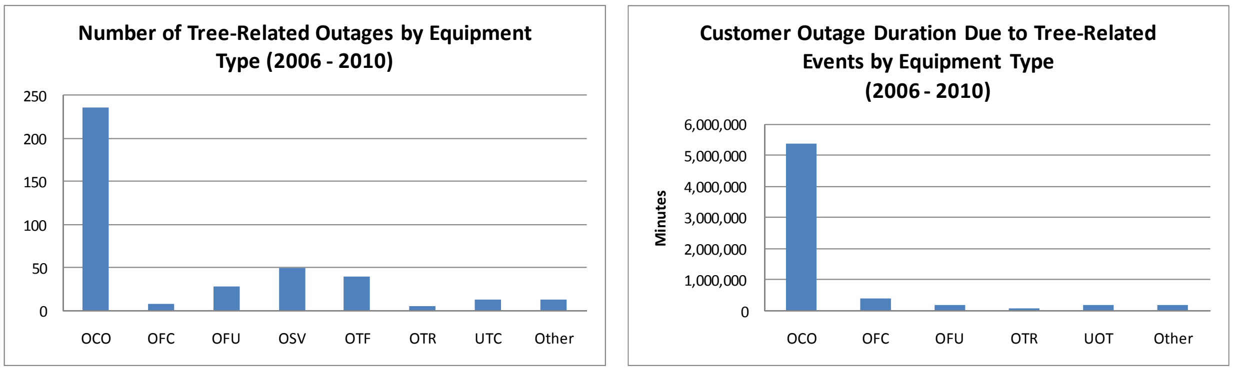


Figure 10. Tree-Related Outages by Equipment Type for Number of Outages and Total Customer Duration[19]

The major pieces of equipment impacted by tree-related events are:

- Overhead conductors (OCO)
- Overhead services (OSV).

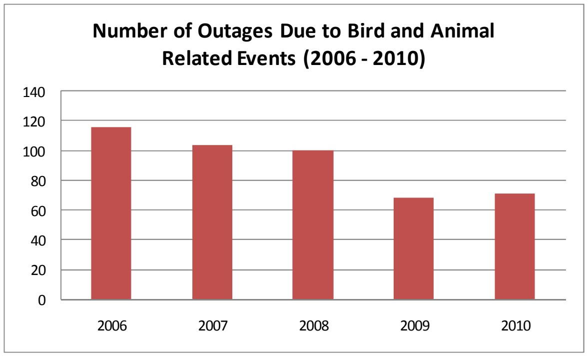
The impact of falling branches or branches coming in contact with lines is the primary cause of faults on the overhead lines. Overhead conductors are the most significant contributor to both number of events and duration because there are many miles of overhead lines and not nearly as many miles of service drops. A visual inspection of circuits in Bellevue shows that there are large trees (both on and off the right of way) that can contact overhead distribution lines and produce faults (and therefore outages).

The reliability measures are based on reviewing sustained outages. For areas affected by tree-related sustained outages, these areas would also be expected to be impacted during major events (such as storms). Therefore, some areas may not show the full reliability picture based on the current data, which excludes storm events.

[19] References 2 and 5–8.

2.2.3.8 Bird and Animal Outage Events

Bird- and animal-related failures are identified as a significant cause of outages in the City. These types of outage events are closely related to tree-related outage events. Figure 11 provides the annual outage trends for equipment failure-related events.



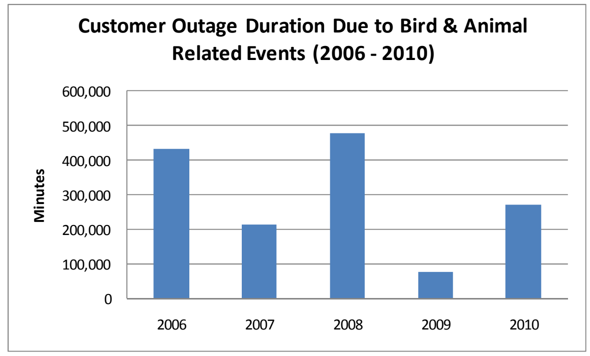
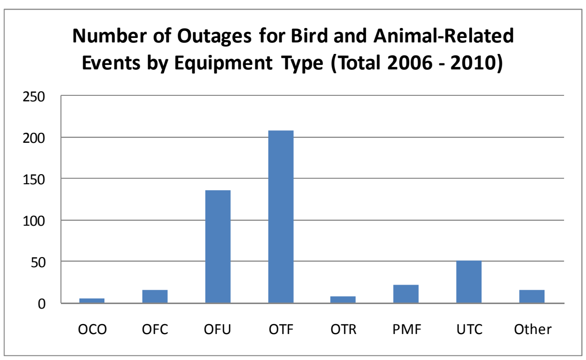


Figure 11. Outage Data in Bellevue Due to Bird- and Animal-Related Events for Number of Outages and Total Customer Duration[20]

The number of bird- and animal-related outages has trended downward over the past 5 years. However, there is no corresponding pattern for duration of events. Bird- and animal-related outages were caused by the following affected equipment as shown in Figure 12.



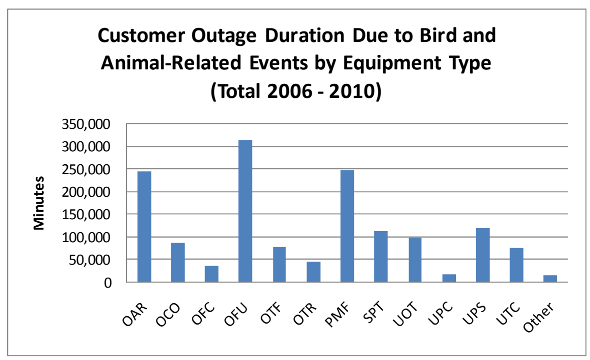


Figure 12. Bird- and Animal-Related Outages by Equipment Type for Number of Outages and Total Customer Duration[21]

The major pieces of equipment impacted by bird and animal-related events are primarily related to overhead equipment such as fuses (OFU) and pole transformers (OTF). These pieces of equipment account for the majority of occurrences. However, animal-related events can occur on non-overhead equipment, such as pad-mounted switch fuses (PMF) and underground fuses (UTF). While these events are low in number, they are significant in duration.

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[20] References 2 and 5–8.

[21] References 2 and 5–8.

For the overhead equipment causes (fuses and transformers), each outage tends to affect a small number of customers. There has been a slight decline in the number of outages per year related to the overhead equipment. The overhead components are relatively easy to identify and repair so that these events are restored quickly. There were a few large outages associated with surge arrestors and pad-mounted switch fuses. These outages affected a large number of customers, and therefore, contributed significantly to the duration statistic despite the small number of events.

2.2.4 Outage Analysis of Representative Circuits within the City

The previous section provided a review of outage causes and related equipment involved in the outages from an overall City perspective. As shown, there has been a general reduction in the overall number of outages and the duration of outages in Bellevue. However, a review of circuits in representative neighborhoods provides additional insight into the reliability of the electric system in Bellevue. Appendix E includes a copy of Figure 32, which provides a map of substation locations in Bellevue.

The selection of circuits for review was based on looking at a set of circuits that were representative of Bellevue—both Downtown and in the neighborhoods. The selection of circuits was based on the following methodology:

- The outage data were compiled by circuit for the overall equivalent SAIDI (duration) and the overall number of events for each circuit in Bellevue for the cumulative 5-year period from 2006 to 2010.
- The circuits were listed from highest to lowest SAIDI to ensure that Bellevue circuits experiencing outages were selected.
- The circuits were then reviewed to select circuits that represented different geographic areas of Bellevue.
- The circuits in specific areas were reviewed for number of customers to ensure that appropriate customer representation was considered.

The listing of Bellevue circuits is provided in Appendix E. Based on this review, the following circuits were selected for further review, including visual inspections:

- Downtown circuits
- Outside Downtown areas (SBE-26 and CLY-23)
- South Bellevue area (SOM-13)
- North Bellevue area (NRU-23 and BTR-22)
- East Bellevue area (LHL-23).

The review of these representative circuits included a visual inspection of the substation and the circuit to assess the equipment layout, condition, and surrounding environment. While the underground circuits were not available for review, the associated substations, surrounding areas, and overall circuit layouts were reviewed. The objective of the representative circuit review was to provide more specific input to the prior outage analysis.

2.2.4.1 Downtown Assessment

The Downtown area of Bellevue receives electrical service primarily from the following substations and circuits:

- Center (CEN-11, -12, -14 and -22)
- North Bellevue (NOB-13, -21 and -22)
- Lochleven (all)
- Clyde Hill (CLY-22, -25 and -26).

The Downtown is served mostly by underground circuits and equipment. However, there has been a recent program to replace the underground equipment with aboveground pad-mounted equipment (transformers and switches). The reliability performance of these circuits is shown in Figure 13.

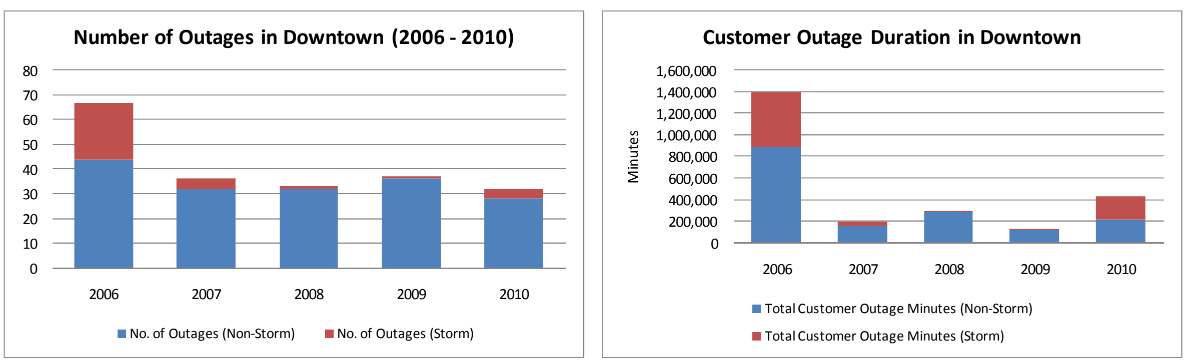


Figure 13. Outage Data in Downtown for Number of Outages and Total Customer Duration[22]

The overall trends show reduction in number of outages and in outage duration. However, in 2010 there was a significant contribution to outage duration caused by major storms that resulted in a circuit outage. Additional information is provided by reviewing the outage cause by type in Figure 14.

[22] References 2, 5–8, and 30.

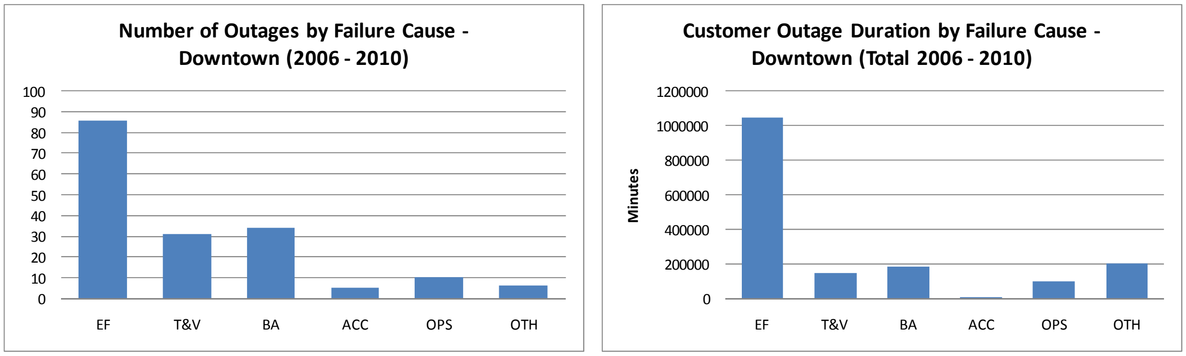


Figure 14. Outages by Failure Cause in Downtown for Number of Outages and Total Customer Duration (2006 – 2010)[23]

Similar to the previous overall analysis, the PSE reports utilize approximately 16 outage type codes. However, for purposes of this assessment, the outage codes have been sorted into six major categories as follows:

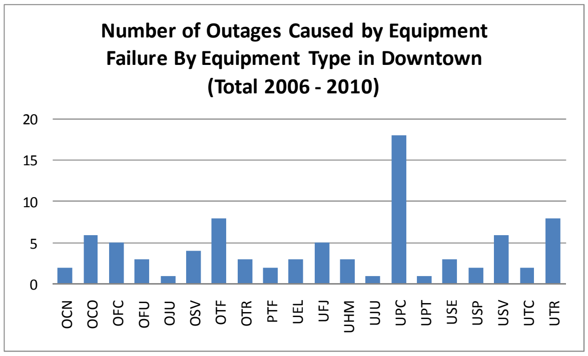
- Equipment failure (EF)
- Trees and vegetation (T&V)
- Bird and animal (BA)
- External accidents (ACC)
- Operations (OPS)
- Other (OTH).

The other category includes items such as installation and manufacturer issues. A list of all the outage types is provided in Appendix C.

This view of outage types indicates that the primary contributor to outage events in downtown Bellevue is equipment failure. There were four "other" outage events in 2006 that resulted in approximately 200,000 outage minutes. Tree-related and bird- and animal-related outages still occur in this area, but with most of the system underground, eliminating equipment problems should be the major focus.

Figure 15 provides a view of outages by equipment type.

[23] References 2 and 5–8.



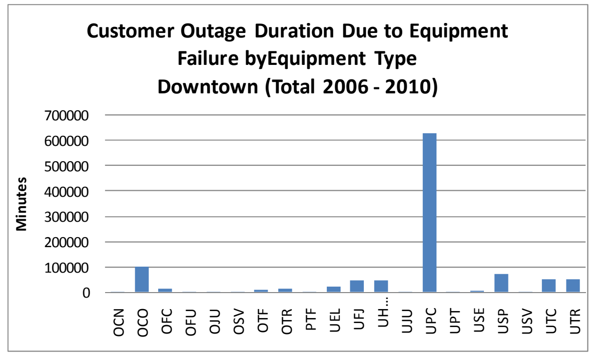
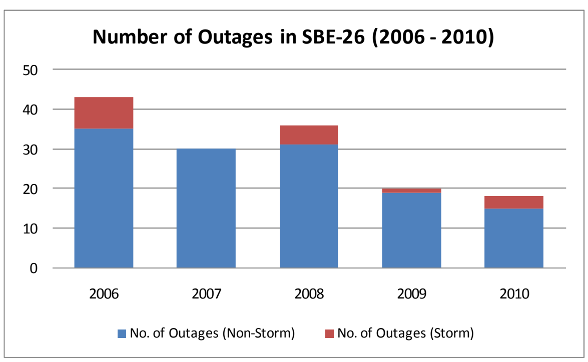


Figure 15. Outages Due to Equipment Failure by Equipment Type in Downtown for Number of Outages and Total Customer Duration (Total 2006–2010)[24]

Based on the review of the outages by equipment type, there are multiple causes of outages, but underground cable failures are the dominant cause of outage duration. Over the past 5 years, PSE has made a significant effort to replace and remediate the underground cables in Bellevue and to increase the ability of the underground system in the Downtown area to deal with contingency situations.

2.2.4.2 South Bellevue (SBE-26) Assessment

This South Bellevue circuit was selected for review as this circuit serves an area south of the Downtown area and has a relatively large number of customers. As is shown in Figure 16, this area has also experienced a high number of outages over the past 5-year period.



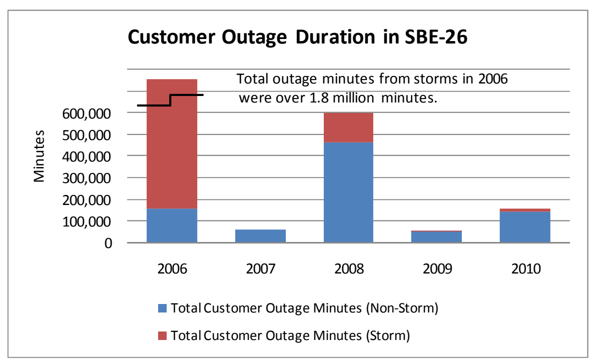


Figure 16. Outage Data in SBE-26 for Number of Outages and Total Customer Duration[25]

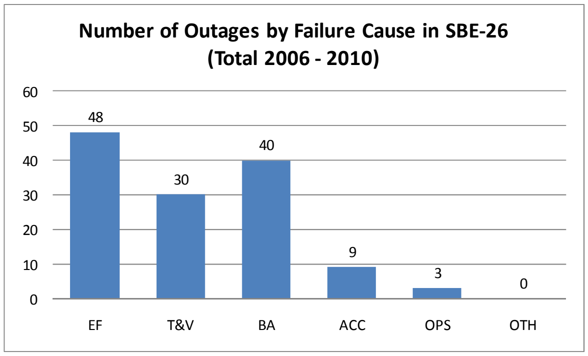
The outage history for this area shows a decreasing number of outages, but the overall duration of the outages varies quite a lot. In 2008, this circuit experienced two large events (one due to an animal-related event at the substation and another one related to an overhead conductor equipment failure) that produced circuit outages which contributed about two-thirds of the

[24] References 2 and 5–8.

[25] References 2, 5–8, and 30.

outage duration minutes. The outages by failure cause are shown in Figure 17. A review of the outage data shows three major causes of failure, which are:

- Equipment failure
- Tree-related
- Bird- and animal-related events.



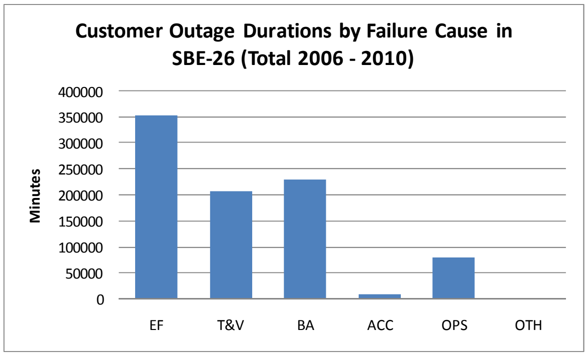


Figure 17. Outages by Failure Cause in SBE-26 for Number of Outages and Total Customer Duration (Total 2006–2010)[26]

Figure 18 shows a view of the substation which shows its location surrounded by tall trees. This circuit is mostly an overhead distribution circuit.[27]

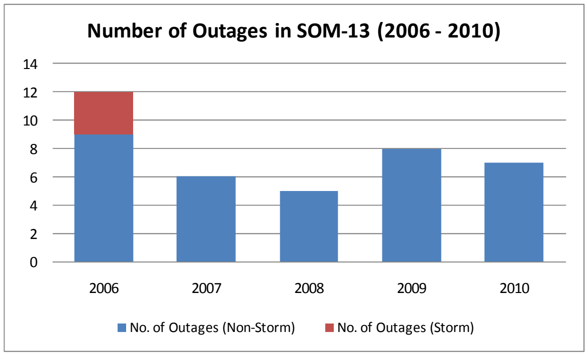
26 References 2 and 5–8.

27 This station would benefit greatly from replacement of the tall trees by shorter varieties that still could provide a visual screen for the substation.

Figure 18. South Bellevue Substation

2.2.4.3 Somerset (SOM-13) Assessment

This Somerset circuit was selected for review as it serves an area in the south end of Bellevue and has a relatively large number of customers. This area has also experienced an increase in outage duration over the past 2 years. The outage trends are shown in Figure 19.[28] The outage causes on this circuit are almost entirely equipment failure-related for both number of outages and duration.



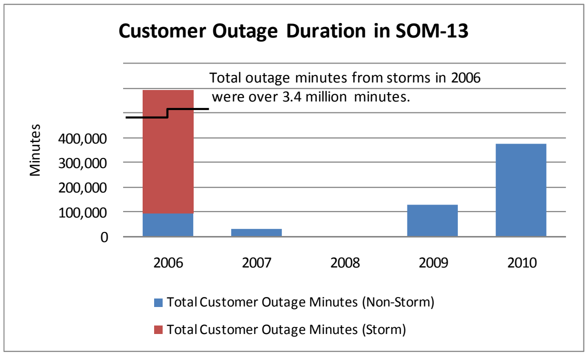


Figure 19. Outage Data in SOM-13 for Number of Outages and Total Customer Duration[29]

This circuit is mostly underground and is currently a radial circuit which is only fed from one substation. In 2010, this area experienced a major circuit outage due to failed cable elbows and

[28] It should be noted that there was a large outage on SOM-16 circuit in 2008 that was produced by a failure in an underground submersible transformer. This event caused a SOM-16 circuit outage that took significant time to restore.

[29] References 2, 5–8, and 30.

junction box. In 2009, failed feeder cables resulted in a major circuit outage. While there are relatively few events on this circuit, the restoration time is significant because there is no alternate power infeeds to the area that can be used to work around the faults. Current plans involve continued cable remediation and the installation of a feeder circuit tie to provide for an additional source of power. These actions are intended to reduce the causes of the outages and to reduce restoration time.

2.2.4.4 Northrup (NRU-23) Assessment

This Northrup circuit was selected for review as this circuit serves an area in the north end of Bellevue and is in a heavily wooded area. This circuit has experienced a significant number and duration of outages in the past. This circuit has both underground and overhead portions of the distribution circuit and has a moderate number of customers. Figure 20 shows the outage trends including a major event in 2008 caused by the failure of an underground cable splice, which accounted for an outage duration of about 350,000 minutes. If this event is excluded, the outage duration trends are relatively constant.

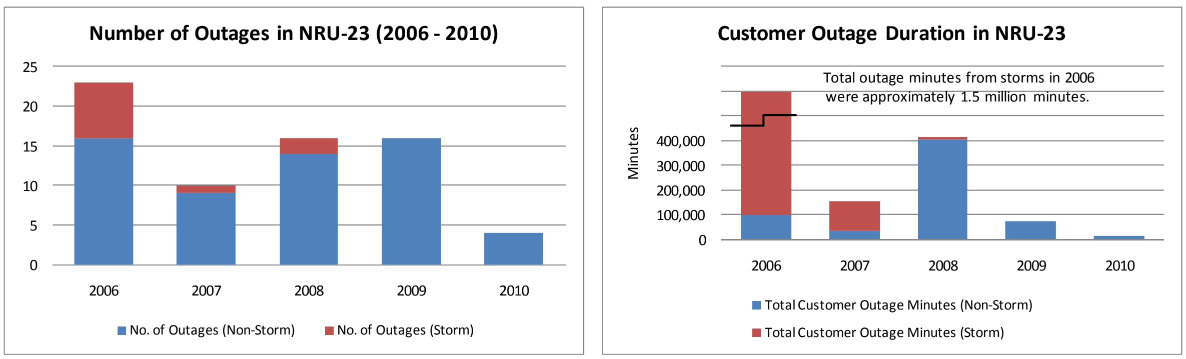


Figure 20. Outage Data in NRU-23 for Number of Outages and Total Customer Duration[30]

An examination of the outages by type is shown in Figure 21. Outages in this area are produced by a combination of equipment failure, tree-related, and bird- and animal-related events. Figure 22 shows the environment around this circuit. The photographs show that the substation and lines are very close to tall trees. The elimination of tree-related impacts is not possible, since falling branches can easily contact the wires.[31] Recent additions of tree wire to attempt to reduce the impact of branches contacting the wires may help reduce outages due to this cause. There is also a major project on this circuit to underground the feeder along NE 24th Street to increase overall performance of the circuit.

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30 References 2, 5–8, and 30.

31 This is another substation that would benefit greatly from replacement of the tall trees by shorter varieties that still could provide a visual screen for the substation.

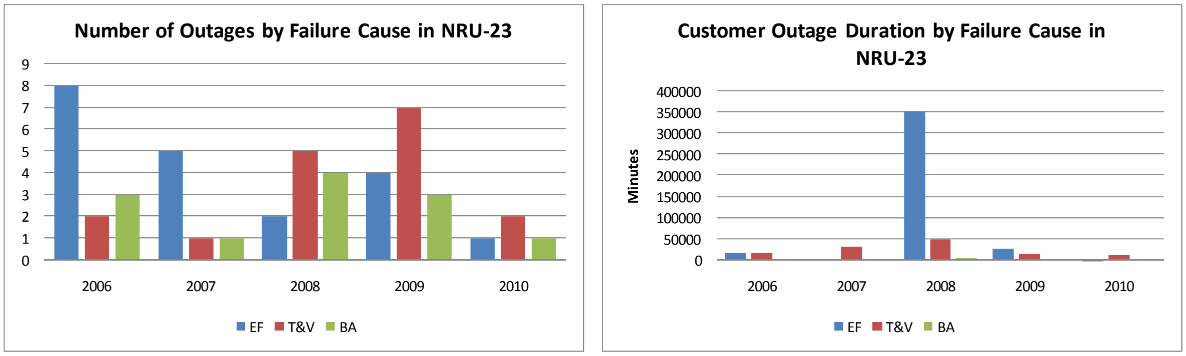


Figure 21. Outages by Failure Cause in NRU-23 for Number of Outages and Total Customer Duration (Total 2006–2010)[32]

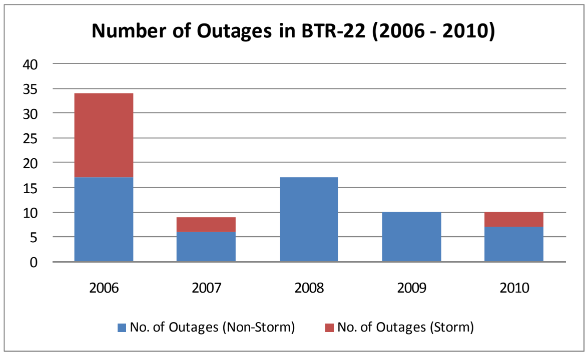
Figure 22. Northrup Substation

2.2.4.5 Bridle Trails (BTR-22) Assessment

This Bridle Trails circuit was selected for review as this circuit serves an area in the north end of Bellevue and is in a heavily wooded area. This area was also identified as an area heavily impacted in the 2006 storm event. This circuit has both underground and overhead portions of the distribution circuit and has a moderate number of customers (similar to NRU-23). The outage trends are shown in Figure 23.

This circuit experienced two significant outages in 2008 (one caused by a tree in the overhead conductors and one caused by failure of a switch and feeder cables). These two outages accounted for about two-thirds of the outage duration during 2008. In 2006, there was a tree-related outage that also accounted for over 50% of the outage duration. Storm-related events also produced significant outage duration in 2010.

[32] References 2 and 5–8.



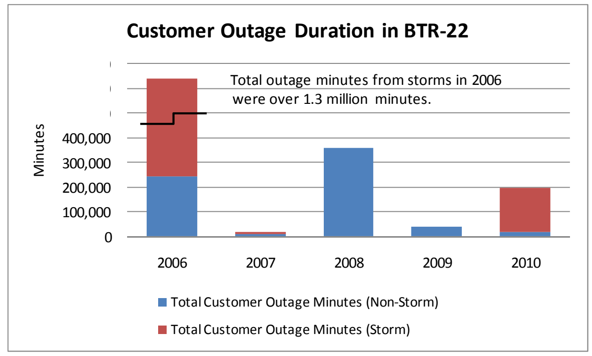
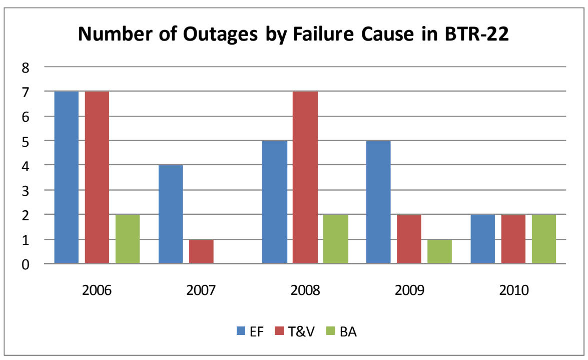


Figure 23. Outage Data in BTR-22 for Number of Outages and Total Customer Duration[33]

Similar to the Northrup circuit, outages in this area are produced by a combination of equipment failure, tree-related, and bird- and animal-related events as indicated in Figure 24. Since this circuit is predominantly overhead and in a heavily wooded environment, elimination of these events is not possible unless the feeder is put underground. However, recent additions of tree wire have been made in an attempt to reduce the impact of branches contacting the wires, which should help reduce outages due to this cause.



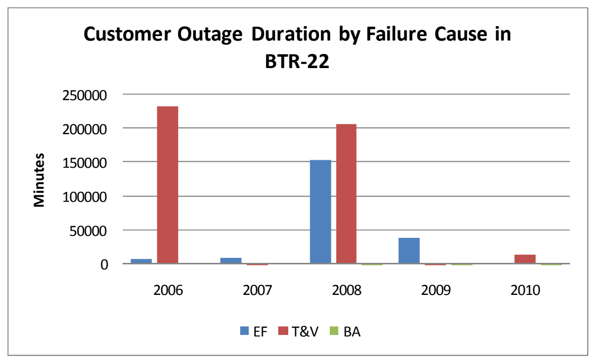


Figure 24. Outages by Failure Cause in NRU-23 for Number of Outages and Total Customer Duration (Total 2006–2010)[34]

2.2.4.6 Lake Hills (LHL-23) Assessment

This Lake Hills circuit was selected for review as this circuit serves an area on the east side of Bellevue with a slightly different environment than that of the north circuits. This circuit has both underground and overhead portions of the distribution circuit and has a large number of customers. The outage trends are shown in Figure 25.

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[33] References 2, 5–8, and 30.

[34] References 2 and 5–8.

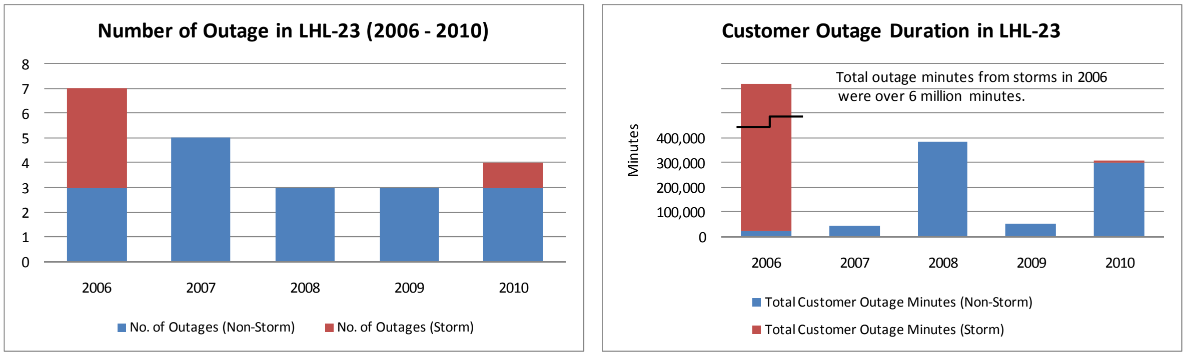

Figure 25. Outage Data in LHL-23 for Number of Outages and Total Customer Duration[35]

This circuit experiences a low number of outages, but shows long outage durations. During 2010, an underground cable failure produced a lengthy outage. The outage was prolonged due to difficulty in locating the failure and restoring the system. This circuit is also a radial circuit that currently is only fed from the Lake Hills substation. Therefore, an alternate power source is not available on this circuit which contributes to the longer duration outages. A similar event occurred in 2008, which resulted in an extended outage. For this circuit, almost all events and durations are attributed to equipment failure (primarily underground cable). There is an ongoing program to monitor and remediate cable in this area to reduce the causes and durations of outages.

2.2.4.7 Clyde Hill (CLY-23) Assessment

This Clyde Hill circuit was selected for review as this circuit serves an area just north of the Downtown and there has seen an increasing level of outage duration. This circuit is primarily an overhead distribution circuit and has a moderate number of customers. The outage trends are shown in Figure 26. Significant outages occurred in 2008, 2009, and 2010 that were tree-related (suspected to be tree branches falling onto the overhead line). There was one outage each year that accounted for the majority of the duration of the outages.

Figure 27 shows a breakdown of outage cause by type. Similar to other equipment in wooded areas, the elimination of these tree-related outages is difficult (Figure 28). There are potential recloser projects identified to sectionalize the line which will improve the ability to quickly restore power to many customers connected to the line after tree branch contact with the line.

[3535] References 2, 5–8, and 30.

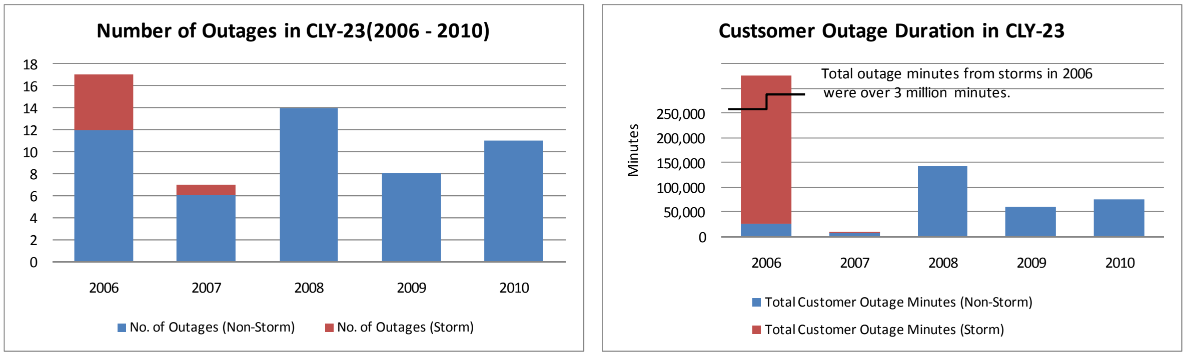

Figure 26. Outage Data in CLY-23 for Number of Outages and Total Customer Duration[36]

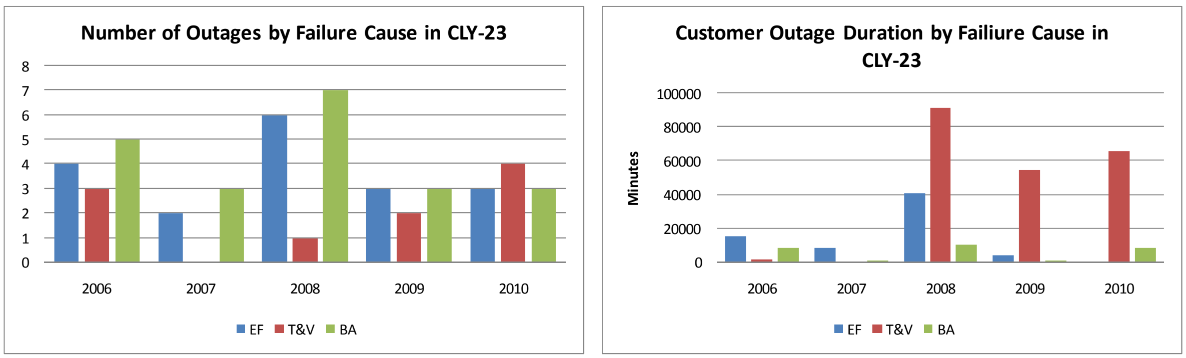

Figure 27. Outage by Failure Cause in CLY-23 for Number of Outages and Total Customer Duration[37]

[36] References 2, 5–8, and 30.

[37] References 2 and 5–8.

Figure 28. Clyde Hill Substation

2.2.5 Summary of the Outage Review

The results of the outage assessment are summarized below with a list of findings and observations, a discussion of potential improvement actions, and a list of recommendations.

2.2.5.1 Findings and Observations

Key observations from a review of the outage data show:

- The overall reliability within PSE's service territory and the City has improved over the past 5 years. Both frequency of outages and duration of outages have shown steady decreases over this period of time. However, performance is not uniform over all circuits and circuits remain in the City that have not shown the same improvement in reliability as the City overall. The inclusion of major-storm outages in the reported reliability metrics (beginning in 2010) provides added input into identifying circuits in need of improvement.

- There are few outages due to substation and transmission line failures. Utilities typically manage electric system assets by focusing maintenance and replacement programs on the assets that have the biggest impact on reliability—transmission lines and substations. Therefore, outages due to transmission line and substation problems are minimized. There is a very small number of outages attributed to equipment failures at substations within the City and on the PSE system.

- Distribution-level assets affect a much lower number of customers per circuit and the equipment is relatively inexpensive and easy to replace. Distribution assets are typically run-to-failure and are replaced when they fail. From an equipment perspective, the major contributors to outages in Bellevue over the past 5 years are underground cable failures and overhead equipment failures (conductors, fuses).

- The number and duration of overhead events related to tree and vegetation effects have decreased slightly over time. However, the potential for overhead line failures in heavily wooded areas remains and cannot be eliminated completely given the height of the trees and often close proximity to the substations and overhead wire rights-of-way. The effects of storms increase the potential for outages due to tree-related events in these wooded areas.

- PSE has performed specific reliability projects for the circuits reviewed previously including:

  - BTR-22: Overhead feeder along 140th Avenue NE was replaced with tree wire in 2007.

  - CLY-23: Underground feeder cables were proactively replaced in 2010. A follow-on companion tree wire project is planned for 2011–2012.

  - LHL-25: A pad-mounted switch together with distribution rebuild provided redundancy.

  - NRU-23: Current projects along NE 24th Street (underground feeder) and 134th Avenue NE.

  - SOM-13: Two cable replacement projects; a system project adding switches to separate distribution sources along Forest Drive; SOM-13 to EGT-12 feeder tie.

A list of reliability projects performed in the City over the past 5 years is provided in Appendix F. This list is based on discussions with PSE around projects that have been identified as projects aimed at improving reliability in Bellevue. These projects were developed to respond to specific events on the circuits based on PSE's review of the circuit performance. These projects directly relate to repair and replacement of equipment, network system enhancements, and automation upgrades. Since these projects address specific problems on the circuits, the selection of these projects should improve overall reliability on the selected circuits. Targeted selection of circuits for improved reliability is an approach taken by utilities to improve overall performance.

The findings above consider issues that affect overall system reliability. When improving reliability, utilities focus on reducing the causes of outages as well as reducing the response time. Potential actions that address the issues identified above are presented below.

2.2.6 Industry Issues and PSE's Corrective Actions

There are several items that dominate PSE's overall reliability performance. These are typical issues facing the electric utilities across the country. Potential improvement actions are discussed below.

2.2.6.1 Underground Cable and Equipment Failures

The utility industry has experienced failures of underground cables due to age of cables and type of construction. Since underground outages tend to be longer outages, prevention of these cable failures or underground equipment failures has a significant impact on both frequency and duration of outages.

Utilities have addressed underground cable failures in the past through repair and remediation of cables. However, recent practice has been to develop proactive cable programs that include:

- Prioritization of cables from a failure perspective
- Continued remediation of cables
- Proactive replacement of cables.

These cable replacement programs consider cable type, manufacturer, age, and failure history. These programs involve identification of the cables most susceptible to failure and proactive replacement (intended to replace cables prior to failure). Additionally, where appropriate, remediation of cable through silicon injection to extend the life of cables is prescribed.

Utilities are placing cables in conduit to allow for better access and to reduce the time to repair cable failures in the future. Distribution automation is also available to improve identification of cable failure locations. Cable failures have been difficult to locate since there is no visible means to identify the location of the fault. The use of fault recorders and installation of Supervisory Control and Data Acquisition (SCADA) systems on switches provide a more effective means of identifying fault locations. Utilities are also installing Distribution Management Systems (DMSs) to improve overall visibility into the distribution system and operability of the equipment.

Underground transformers and switches that are placed in vaults are susceptible to failure due to equipment aging and environmental impacts (water and corrosion). The replacement and repair of this equipment is difficult due to limited access into the vaults. Utilities experiencing a large number of failures of these equipment types have developed proactive replacement programs to replace older equipment models.

2.2.6.2 PSE's Corrective Action Initiatives

From the perspective of the City, Bellevue was one of the first areas of the PSE system to use underground cable and equipment, and the age of the cables and design approach (direct bury) has resulted in a large number of equipment failures due to aging. PSE has implemented a system-wide (including Bellevue) underground cable program to reduce the potential for cable failures. The PSE program includes all the elements of cable replacement and remediation. Additionally, PSE is utilizing conduits for the cables to further extend the life of new cable.

PSE has implemented a strategy to replace older less reliable underground switches and when possible, is replacing these with aboveground equipment. The aboveground equipment provides greater accessibility to speed up outage recovery.

The development of an active cable replacement and remediation program as well as replacement of aging and problem equipment is an appropriate action to improve system reliability by reducing the number of equipment failures. Additionally, the use of more modern technology is expected to result in a system with longer asset life.

2.2.6.3 Overhead Conductor and Equipment Failures

Overhead equipment is also susceptible to aging-related failures. However, overhead systems are also subject to the effects of tree-related faults due to storms and wind, bird- and animal-related events, and damage due to vehicle accidents. Given the environment in Bellevue, the effects of storms and weather have an impact on system reliability. Most utilities address overhead equipment performance through vegetation management, wildlife management, and pole and line inspection programs to limit the potential for faults on the overhead distribution system. Also, overhead equipment is typically low cost, not easy to test *in situ*, but easy to repair, so the common practice is to run these pieces of equipment to failure at which time they are replaced.

2.2.6.4 Conversion of Overhead Line to Underground Circuits

Another means to address overhead susceptibility to weather and tree-related events is undergrounding. Underground systems, while susceptible to other outage causes, are not as vulnerable to wind and weather events, but are also susceptible to damage through soil excavation and potentially earth quake damages. Many utilities now install underground distribution systems for new installations. Through the Comprehensive Plan (Policy UT-39), the City already requires undergrounding of new distribution lines. Replacing overhead lines with underground cables is a different issue since the cost for such a conversion is at present not covered. Conversions of overhead systems to underground are not common in the industry. Since the cost of underground systems is significantly higher than overhead systems, the common practice requires the party benefitting from the underground conversion to pay the difference in cost between overhead maintenance and replacement and the cost of undergrounding. The Edison Electric Institute[38] performed a study to investigate the conversion of overhead lines to underground systems. While the report does not specifically address conditions in Washington, it does provide a comparison of the costs of overhead and underground construction. A summary of this information is provided in Table 2 below. This information specifically applies to distribution systems.

[38] Reference 12.

Table 2. Cost of Overhead vs. Underground Construction (Cost per mile)[39]

Location	New Construction Overhead (Average)	New Construction Underground (Average)	Conversion from OH to UG (Average)
Rural	$135,000 approx	$410,000 approx.	$395,000 approx.
Suburban	$200,000 approx.	$570,000 approx.	$725,000 approx.
Urban	$200,000 approx.	$560,000 approx.	$830,000 approx.

The state of Washington does have provisions relative to conversions. Revised Code of Washington (RCW) 35.96[40] specifies requirements that allow cities or towns to create local improvement districts and to levy and collect special assessments against real property benefitting from the conversion of overhead facilities to underground facilities. PSE also has a tariff that provides a basis for performing work for others (Electric Tariff G 73 and 74 for conversion to underground for non-government and government entities, respectively).

There is very limited precedence for allowing regulated utilities to place underground conversions into the rate base. California has Rule 20 which allows cities, on a limited basis, to identify areas for undergrounding under very specific safety criteria. Rule 20 projects require pre-approval from the California Public Utilities Commission. However, at the completion of the conversion, the cost is added to the utilities' rate base. Duke Energy Carolinas is also considering a pilot program to work with municipalities to place qualifying areas underground with some cost sharing between the utility and municipality.

2.2.6.5 Vegetation Management

The implementation of effective vegetation management, wildlife management, and pole inspection programs provide industry-accepted means of preventing overhead line failures. The selected use of "tree wire" also is an appropriate method to reduce faults on overhead conductors that produce outages from tree-related causes. Undergrounding of lines minimizes storm and weather impacts and the City already requires new installations to be constructed underground. All of the above represent positive solutions to the prevention of outages.

PSE has vegetation management, wildlife management, and pole and line inspection programs comparable to others in the industry. These programs are described in more detail later in Section 2.4. PSE has also utilized tree wire to reinforce the overhead lines in certain areas with success. The tree wire is a covered conductor and reduces the potential for faults due to tree contact. Tree wire is heavier and provides some support against larger branch contact. However, tree wire has both positive and negative attributes. While the covered conductor helps to reduce faults, the covered conductor also increases the potential for a downed line to

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39 Reference 12, Figure 6.3 (new construction) and Figure 6.4 (conversions)

40 Reference 25.

remain energized creating potential safety hazards. However, this safety issue also exists to some extent for bare wire.

2.2.6.6 Distribution System Automation

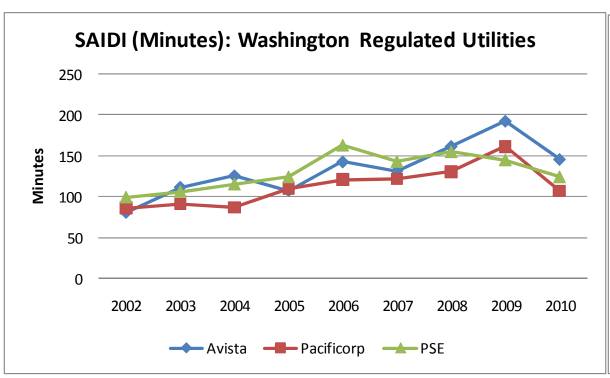
The use of automation, including the use of SCADA systems, for remote control of breakers and switches provides the means to reduce the outage duration due to overhead but also underground outages. The installation of reclosers to automatically re-energize a line after a fault provides an effective method of reducing outage duration (especially due to "quick" tree interactions with the conductors). While these do not eliminate faults, they allow the system to respond automatically if the fault clears due to some momentary contact between the line and a tree. PSE is implementing the use of such reclosers and distribution system automation to improve its overall outage response. There are other design features available for reduction of the duration of outages that are described later in Section 2.3.

A key factor in improving reliability, therefore, needs to be focused on reduced outage recovery times and outage management in addition to the activities above. Outage management activities are discussed in Section 2.4.6.

2.2.7 Comparison between PSE and Other Utilities

PSE participates in an industry reliability survey through IEEE. PSE's overall system reliability performance is typically in the 1st or 2nd quartile on frequency of outages and 2nd or 3rd quartile in duration of outages (with the 1st quartile being best performance). The overall reliability performance in the City is significantly better than that of the overall system. This was to be expected as Bellevue represents one of the densest areas of the PSE service territory. Typically these urban areas have more built-in system redundancy and therefore, should experience fewer outages and shorter recovery times. Additionally, faster recovery is enhanced by the proximity of the urban areas to service centers for restoration.

WUTC also reports reliability indices for its three regulated electric utilities based on the IEEE criteria for SAIFI and SAIDI. As shown in Figure 29, PSE's performance is comparable with the other regulated utilities in the State.



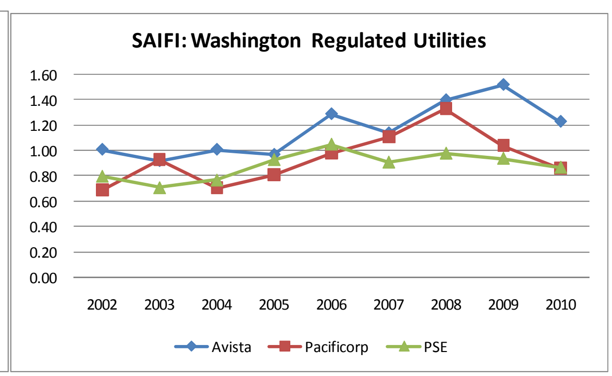


Figure 29. Washington Regulated Utilities SAIFI and SAIDI Results

Additionally, Seattle City Light (not regulated by the WUTC) reports in its 2010 annual assessment that it achieved its SAIFI goal of less than one. Therefore, on an overall basis, PSE is comparable to other utilities within the state, and the City overall has significantly better performance.

Lawrence Berkeley National Laboratory (LBNL) performed an assessment of the electric power system based on 2006 data. The industry reliability indices reported in 2006 based on the LBNL study (Reference 3, Table 2) indicate an average SAIDI of 244 minutes per customer and an average SAIFI of 1.49. The values in the western U.S. (Pacific Region as defined in Reference 3, Table 2) are considerably higher at 296 minutes and 1.99, respectively for SAIDI and SAIFI. The Pacific Region is defined as the states of Washington, Oregon, California, Alaska, and Hawaii; and includes information from the only 12 regulated utilities that provided information. From an overall perspective, the performance in the PSE area appears better than the industry in 2006.

A further review of the LBNL report indicates that most utilities report information using greater than 5 minutes as the basis for a sustained outage. Less than a quarter of the utilities reporting use greater than 1 minute for sustained outages. It should be noted that PSE utilizes the 1-minute rule for reporting its reliability indices. For the subset of utilities reporting using the 1-minute rule, the average SAIDI and SAIFI are 143 and 1.4, respectively. The PSE performance during this time period shows that PSE has a higher SAIDI value, but a lower SAIFI value. The LBNL also addresses reliability with major event information included. PSE had not reported this information prior to 2010, but this information has been requested by WUTC and, beginning in 2010, is a part of the annual reporting requirements[41]. The requested metric is a 5-year rolling average so, for now, this metric is not a good basis for comparison.

Another aspect of comparison with other utilities is customer satisfaction. JD Powers conducts surveys of electric utilities that measures overall customer satisfaction. The survey measures utility performance around six key factors: power quality and reliability, price, billing and payment, corporate citizenship, communications, and customer service. The survey indicates that a key to achieving customer satisfaction is the management of customer expectations as they relate to outages and restoration of service. If utilities manage expectations around outages, this effort may have a positive influence on customer satisfaction. In the latest survey by J.D. Power and Associates,[42] PSE ranked in the top half of large utilities in the Western Region Large Segment. The PSE scores placed them above the average and also in range with other utilities in the Northwest. In the 2010 survey,[43] PSE scored just below the midpoint of Western Region Large Segment utilities. This information provides another benchmark for performance against peers, but a key finding is that communication around outages is a major factor in overall customer satisfaction. As indicated in the review with stakeholders and the City, the communication around outage status was identified as an important element and a key area for improvement.

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41 Reference 4.

42 Reference 31.

43 Reference 32.

2.2.8 Recommendations

Based on the outage assessment and the current status of PSE's programs to respond to these events, the following recommendations are made to improve the City's ability to be a more proactive participant in improving reliability:

- There are several programs underway to address prevention of outages and to reduce duration of outages. The City can and should proactively monitor the progress and extent of those programs focused on improving the reliability of the City's power distribution system. This will require the City to add staff with power system know-how.
- The City should investigate opportunities for additional undergrounding of distribution lines through coordination of multiple-utility projects and evaluation of funding for conversion of overhead lines to underground cable circuits by forming local improvement districts.
- PSE has ongoing reliability initiatives and performs system-wide and targeted projects to improve system reliability. The City should track the reliability impacts experienced in the various neighborhoods. Since, in the future, PSE will be reporting additional reliability information including storm outages, the City can utilize this information to determine the effectiveness of the various reliability programs and projects, and to work with PSE in identifying circuits requiring attention. A fast track implementation of system improvements is an option for the City to explore with PSE, although accelerated investments might have a negative impact on the power rates.
- The visual review of overhead circuits indicates that there are many substations and lines located in heavily wooded areas and the only way to significantly improve reliability is to perform more comprehensive tree trimming. The City should review its vegetation policies, specifically in the substation areas, to look at alternate vegetation approaches where the risks for large-scale disturbances related to vegetation issues is high.

The remainder of the section provides a discussion of the overall system design and work processes relative to the potential for reliability risk.

2.3 Review of PSE's System Design

2.3.1 Scope

System design has a major impact on electric reliability from the standpoint of limiting outages and reducing the restoration period in response to events. This section provides an assessment of the current PSE system relative to the overall design and layout of the Bellevue distribution system. The review of PSE's system design is intended to identify potential opportunities or vulnerabilities in the overall electric power system relative to reliability within Bellevue.

2.3.2 Approach

The assessment was performed solely through a review of publicly available WUTC documents, publically available PSE and other documents, and limited discussions with PSE's staff. In addition, a walk-through of PSE's substations and control centers was a part of the review in order to obtain an understanding of PSE's design practices. PSE proprietary and confidential documents were not made available for the review. The information reviewed for this assessment is listed below and was discussed with PSE personnel during meetings on these topics:

- Distribution System Design, Loadings, and Operations
- Transmission System Design, Loadings, and Operations
- Capital Project Planning and Prioritization
- Projects and Reliability Initiatives in Bellevue
- Substation and Line Maintenance and Problem Investigations
- PSE Electric Substation Work Practice Standards
- PSE Electric Relay Work Practice Standards.

The WUTC information included in Washington Administrative Code (WAC) 480-100 series was also reviewed as part of this assessment.

2.3.3 State of Washington Requirements

2.3.3.1 Relevant State Codes

WUTC provides oversight of electric utilities through regulations codified in WAC Chapter 480-100. As noted in WAC 480-100-001, the purpose of these regulations is "to administer and enforce chapter 80.28 of Revised Code of Washington (RCW) by establishing rules of general applicability and requirements for consumer protection, financial records and reporting, electric metering, and electric safety and standards". The principal statutes that define WUTC's authority and responsibility with respect to electric utilities are found in RCW Title 80. WUTC regulates electric non-public power utilities, such as PSE[44]. These laws provide the basis for the operations of the electric utilities and how they must conduct business. A more detailed discussion of the regulations and their impact on system reliability is provided in Section 4.2.1.

A brief summary relative to the regulatory impacts on reliability are:

- Requirements for maintaining fair rates subject to rate case hearings: These requirements have an impact on the utility's capital expenditures and projects selected each year.

[44] WUTC does not have jurisdiction over the Public Utility Districts (PUD) or Municipal Utilities.

- Requirements for power quality that define voltage range provided to the customers: This item requires both the utility and end-users (major industrial or power users) to manage their assets to minimize voltage fluctuations on the system.
- Requirements for submitting annual reliability reports: Regulated utilities are required to submit reports on electric system reliability and on actions taken to improve reliability. This requirement also has a major impact on the selection of capital projects and maintenance each year.
- Requirements for interacting with jurisdictions relative to access to rights-of-way in order to maintain a safe and reliable system.
- Guidance on renewable, energy efficiency, and environmental concerns: The State provides requirements and incentives to utilities to promote reductions in power use and the use of environmentally friendly power sources.

2.3.3.2 PSE's Regulatory Environment

Based on this review it was concluded that the state of Washington has codes and requirements similar to other states. However, the code requirements are less detailed than, for example, those of the state of California, which has issued detailed regulations in regard to design, operation, and maintenance of the electric power system.[45] California's key code sections are:

- General Order 95—Rules for Overhead Electric Line Construction
- General Order 128—Rules for Construction of Underground Electric Supply and Communication Systems
- General Order 165— Inspection Cycles for Electric Distribution Facilities.

That is, the state of California has issued detailed rules for design, construction, and maintenance of facilities. No similar rules have been found among WUTC's rules. Thus, it appears as if PSE can design and operate its power system with a higher degree of freedom. However, it still has to meet prevailing standards such as the National Electric Safety Code.[46]

According to information provided by PSE, expenditures and investment costs to be included in the rate base are not reviewed and approved in advance by WUTC but are reviewed after the expenditures and investments have been made. That is, PSE carries the entire risk for investment decisions that it makes until the investments have been made and are presented to WUTC for inclusion in the rate base. If WUTC does not find the investments or expenditures to be prudent it might not allow for these costs to be included in the rate base. In some other states, such investments may have to be preapproved by the regulators prior to initiating the project or starting construction.

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[45] See http://docs.cpuc.ca.gov/gos/index.html for information about the California codes.

[46] IEEE Standard C2-2012 National Electric Safety code: ISBN: 9780738165882 (Latest Issue).

2.3.4 Review of PSE's Power Supply

Electric reliability depends on a stable power supply. Relative to the City, the power supply starts with generation and transmission assets feeding the distribution assets in Bellevue. Since the power flows to whatever loads are connected, it is not possible to evaluate the power generation portion specifically related to Bellevue. The Bellevue-specific aspect of the power supply relates to having transmission lines that are capable of supplying the generated power to the City. This section provides a brief synopsis of the current power supply situation for Bellevue.

2.3.4.1 Risk Analysis—Present Generation Capacity

Generation capacity has been sufficient to support the overall PSE electric demand at present, including Bellevue. However, issues have arisen about the ability of wind energy to be delivered through the transmission system in the Northwest from wind power plants in eastern Washington, Idaho, and Oregon.[47] This has not caused power supply problems for Bellevue but indicates that the location of PSE's power supply sources is important and that bottlenecks exists outside of PSE's service territory that can impact how much power PSE will be able to transfer over transmission lines that are not owned by PSE. The risk to Bellevue related to insufficient generation available to PSE cannot be quantified because data are lacking to enable such an analysis. A detailed discussion of generation issues is provided in Section 3 with the review of the Integrated Resource Plan (IRP).

2.3.5 Risk Analysis—Bulk Power Transmission System for Bellevue

2.3.5.1 Scope

PSE operation depends on power wheeling over relatively few transmission lines. This task entailed reviewing the contingencies under which PSE might lose all or a significant amount of the power it needs to keep its customers supplied with electric power in order to assess any potential risks to reliability.

2.3.5.2 Present Transmission System Design

The City receives its electric supply via a 115 kV looped subtransmission system that is connected to primary substations at Sammamish (to the north) and Talbot Hill (to the south). These two stations, in turn, are connected to the high-voltage transmission grid that serves the northwestern states, and receive energy from a mixture of fossil fuel and renewable sources, often located many miles away from Bellevue. The 115 kV lines roughly encircle the City and feed several distribution substations, which step the voltage down to 12.5 kV, a voltage which can more readily be routed through the neighborhoods of the City. It is important to note that most (although not yet all) of these distribution substations are fed from the 115 kV system using two different lines, a method which provides redundancy should one line experience a

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[47] See http://www.nytimes.com/2011/11/05/business/energy-environment/as-wind-energy-use-grows-utilities-seek-to-stabilize-power-grid.html for a discussion of wind power issues in the Pacific Northwest.

fault or if maintenance on a line is required. On the 12.5 kV system, the service transformers, whether located on poles, underground, or as ground-level "pad-mounted" units, further reduce the voltage to the familiar ones we all use, such as 120, 240, or 480 VAC, and also provide 3-phase service to commercial and industrial customers.

Figure 30 provides a map of the existing 115 kV system for the City and the surrounding area. The map also shows an existing, double circuit (two 3-phase circuits on one pole) 230 kV line that is owned by Seattle City Light which is not available for power transmission into the City, although the line affects the power flows on other lines owned by other entities in the region. PSE has two 230 to 115 kV, 325 MVA transformers and three 115 kV lines feeding power north up to the City from its Talbot Hill substation. The two lines from Talbot Hill to Lakeside carry about 157 MW each under N-0 conditions (normal winter peak load with all circuits in operation).[48] The map also shows five 115 kV circuits feeding power from the north into the City. These terminate in the Sammamish substation, where there are also two 230/115 kV, 325 MVA transformers installed to feed power into the 115 kV lines.

The Talbot Hill and Sammamish substations receive power from 230 kV lines connected to the Bonneville Power Administration's (BPA) Maple Valley substation (which is shown in Figure 31) and from its Monroe substation to the northeast of Sammamish. The Maple Valley substation is located a short distance to the east of Talbot Hill. Figure 31 also shows the 230 kV line that comes from BPA's Monroe substation to PSE's Novelty Hill substation (not shown on the BPA map) and from there a transmission line extends west where it is terminated in PSE's Sammamish substation, which has a total of three 230 kV line terminations. One of these is leased from BPA by PSE. This line loops south from Sammamish via Klahanie to BPA's Maple Valley Substation. This lease expires in 2018 at which time the lease has to be renegotiated or the line reverts to BPA's control. The third line connects PSE to the Seattle City Light substation at Bothell.

[48] Reference 33 (Section 28, Reliability/Availability of Systems). N is the number of elements in the system and the minus zero designation means that no element is missing or out of service.

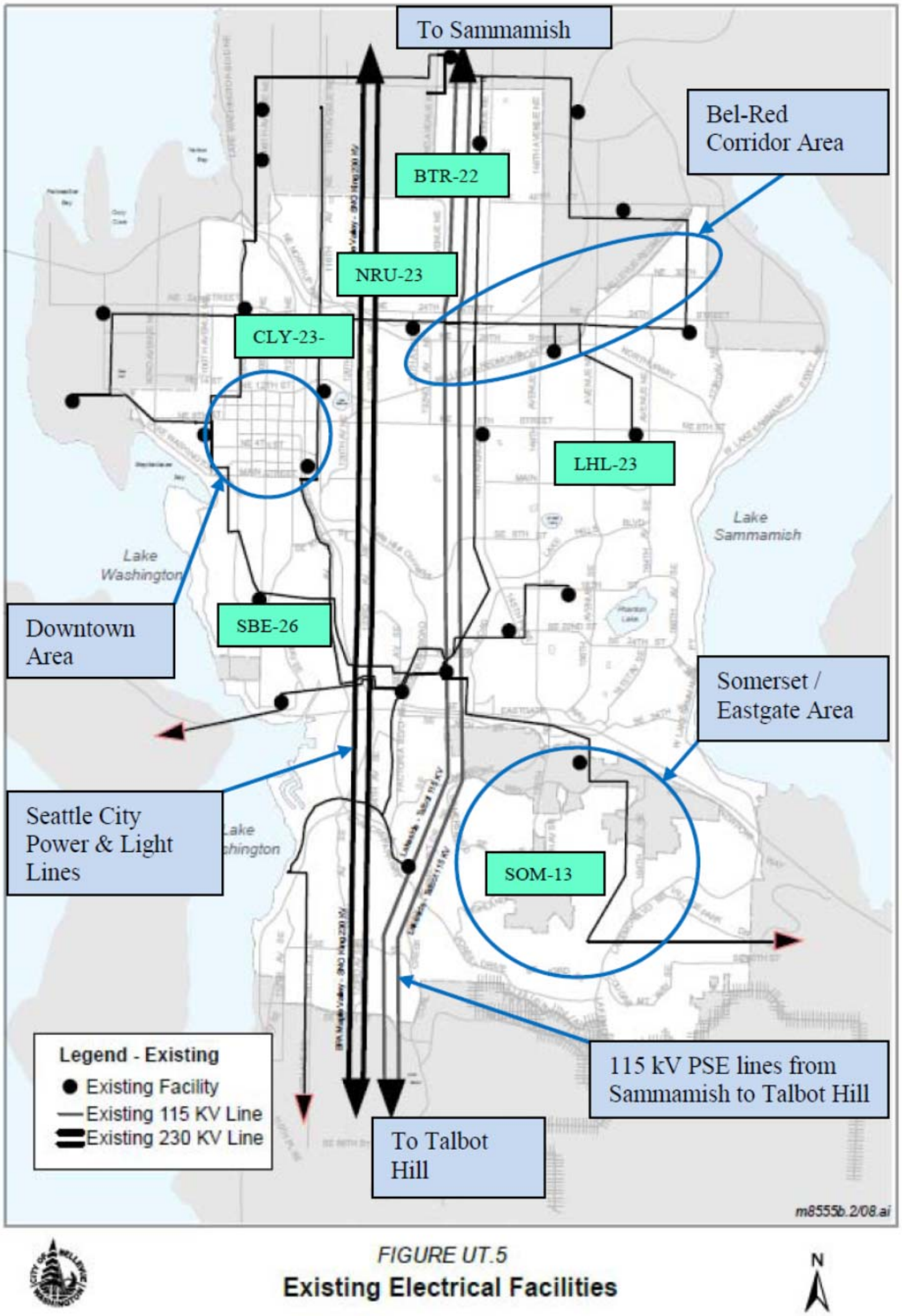

Figure 30. Existing Transmission Facilities around the City of Bellevue

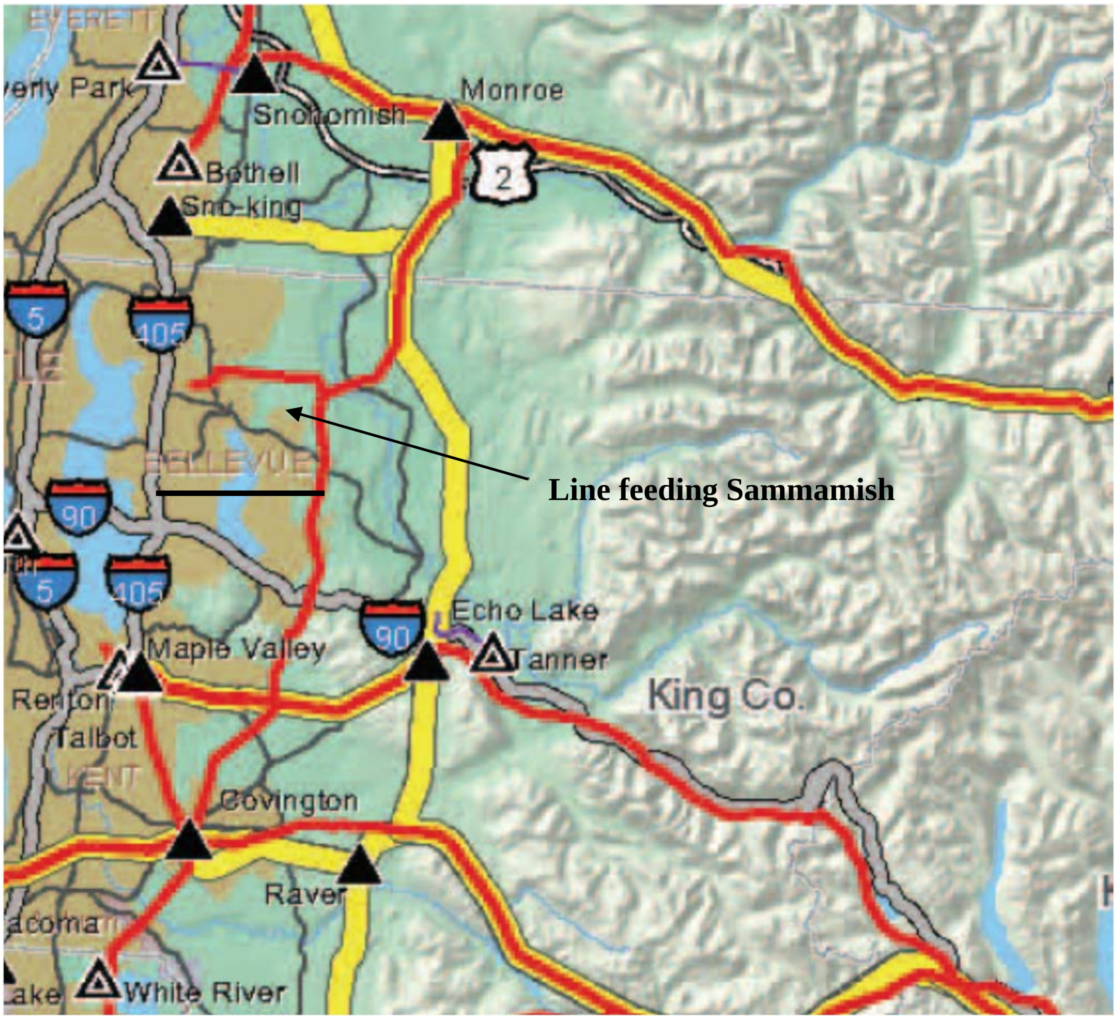

Figure 31. BPA's 500 kV (Yellow) and 230/345 kV (red) lines East and South of Bellevue

2.3.5.3 Bulk Power (230 kV) Transmission System Assessment

BPA's Maple Valley substation is a strong source supplied via 500 kV lines, whereas the Sammamish substation receives its power via longer 230 kV circuits from the Monroe, Bothell, or Maple Valley substations. (PSE also owns a 230 kV line going from Sammamish to the Bothell substation, which is owned by Seattle City Light.)

A loss of the 230 kV line to Monroe or the one to Maple Valley (N-1 contingency) is a serious stress to the City's power supply but should not cause any outages in the City.[49] There will be a future need for better voltage support to the Sammamish substation in order to support growth in the City and the surrounding areas.[50] Conversion of one of the 115 kV lines between Talbot

[49] Loss of the 230 kV lines from BPA was one of the reasons (but not the only one) for the widespread power outage in 2006. (Based on interview with PSE personnel; see also Reference 34)

[50] Interview with PSE planners.

Hill and Sammamish to 230 kV and installation of a 230/115 kV, 325 MVA transformer in the Lakeside substation will also be needed to support the region's expected future growth.

2.3.6 115 kV Transmission System Review

2.3.6.1 Scope

PSE's 115 kV system is considered a subtransmission system with transmission service being provided by BPA. This review consisted of assessing PSE's 115 kV transmission system, since disturbances on the 115 kV system would be most likely to cause power system disturbances in Bellevue.

2.3.6.2 System Load Scenarios and Planning Assumptions

PSE is a winter peaking utility. Therefore, transmission system outages have a larger impact in the winter than a similar outage during the summer period, since the summer peak load is only about 65% of winter peak.

PSE has not experienced any load growth since 2008. The planned growth has therefore been shifted foreword by a couple of years. The present planning criteria is for 0.5% annual growth for the immediate future and a growth rate of about 1% per year for the next 10 years.

PSE builds its transmission infrastructure to minimize outages and avoid overloads on the 115 kV transmission system on an N-1 basis (N-1 is the first contingency). This is defined as a Category B event by the North American Electric Reliability Corporation (NERC). NERC defines a Category C event as an N-2 contingency case (two simultaneous events). An example of this is a breaker failure (the first event) that would lead to clearing all circuits connected to a substation bus (the second event). For this contingency, according to the NERC rules, PSE is allowed to drop non-consequential load.

PSE also tries to minimize many so called N-1-1 events. That is, with one outage in the system, planned or unplanned, it tries to be in position to handle a second, unplanned outage. However, this is not possible for some portions of the 115 kV transmission system where a portion of the City is fed via a single 115 kV line. A loss of this line might cause power disruptions to a portion of the power users in the City. For example, as is shown in Figure 32, the loss of the single, radial line to Lake Hills would cause a loss of power to those connected to the substation, unless power can be provided via a looped 12.5 kV distribution circuit that can be fed from another 115 kV substation.

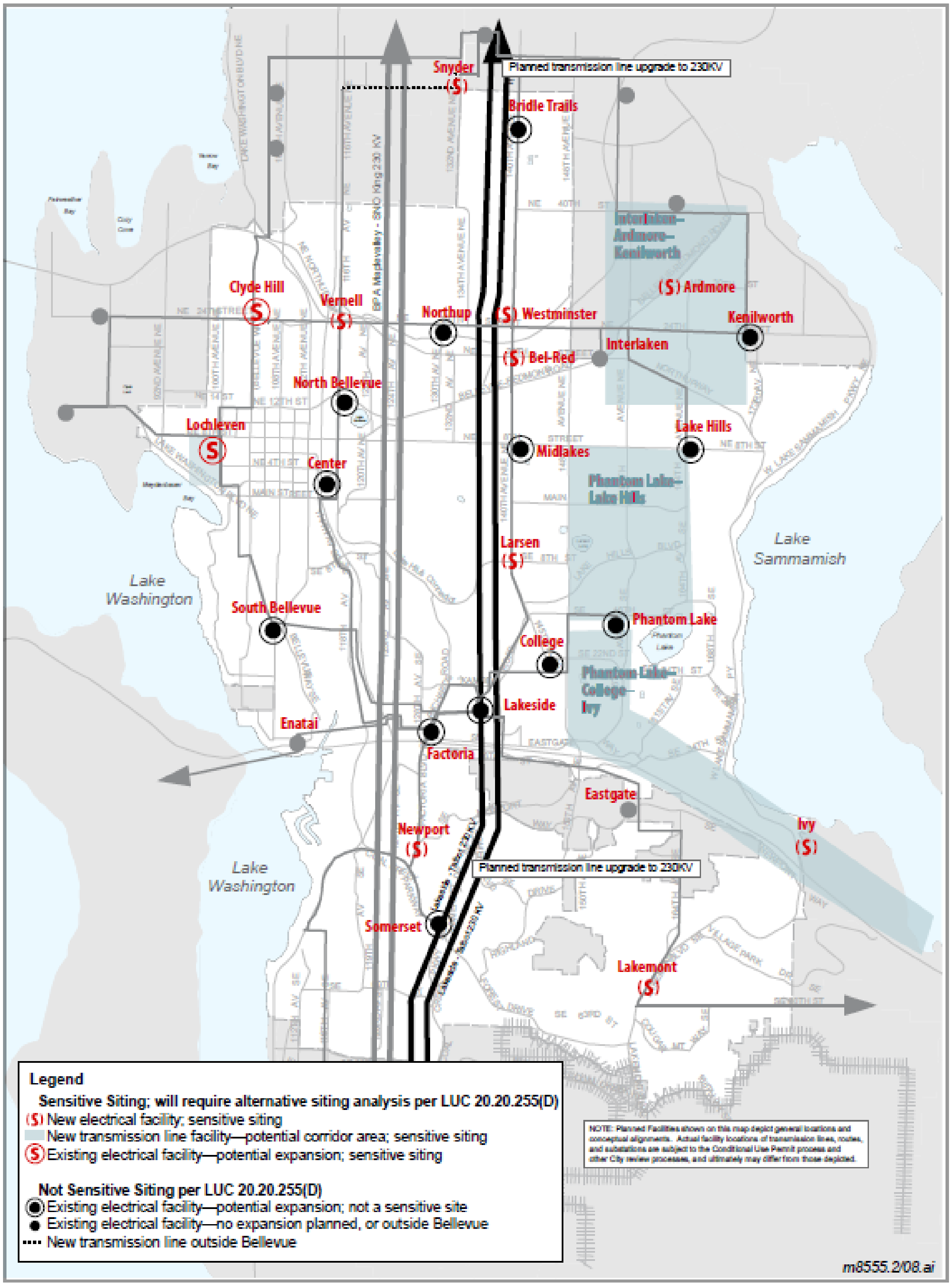

FIGURE UT.5a

New or Expanded Electrical Facilities

Figure 32. PSE's Expansion Plan for Bellevue

A line between Lake Hills and Phantom Lake, which is in the process of being designed, is needed to supply these two substations from two directions. This should meet the N-1 criteria but might not meet the N-1-1 condition since an outage on this circuit would still affect the customers connected to the line if the line is lost when a section of the line is out of service. This is also true for the Downtown area that is fed via a line from South Bellevue to Sammamish. This circuit will also survive an N-1 but not an N-1-1 scenario.[51] To survive this without a loss of power to the customers, three circuits have to be feeding each substation or each 12.5 kV distribution circuit has to be connected to two substations fed from different 115 kV lines.

According to PSE's planners, the worst case outage is the loss of a transformer in Talbot Hill, in which case the second transformer could be overloaded. For this case, the load on this transformer has to be reduced and shifted over to Sammamish.

2.3.6.3 115 kV Transmission System Analysis

PSE has upgraded the 115 kV transmission line conductors to be capable of operating up to 100°C (212°F). This allows the lines to be loaded higher under contingency situations to avoid having to drop loads. (The 230 kV line between Bothell and Sammamish has been upgraded to 200°C, which requires special "hardware" capable of operating at such high temperatures.)

Contingencies that might cause outages are:

- Lakeside to Sammamish with Kenilworth line open: Under these conditions, a loss of the transmission line from Sammamish or Lakeside could cause customer outages.
- Work on Lakeside to South Bellevue would drop load in Bellevue if any second fault would occur. A new line to Clyde Hill from Sammamish would be needed to avoid such outages.

Other similar examples of contingencies that would result in outages exist in and around the City. To avoid outages, the 115 kV system needs to be reinforced.

2.3.6.4 Comparison to Other Utilities

PSE's planning assumption to operate under N-1-1 scenarios for its 115 kV system is consistent with good planning for power distribution systems at feeding distribution substations. However, PSE is not able to meet these criteria for some areas of its service territory because of not having 115 kV circuits to provide the additional power infeeds to some substations. This primarily affects residential neighborhoods. It would not be unusual to find the same situation in many other utilities.

[51] PSE has stated that it avoids planned outages on the circuit during the fall and winter seasons to minimize the risk of a power outage that would affect the downtown.

2.3.6.5 Recommendations

To achieve high reliability of the power supplied via the 115 kV power transmission lines, it is recommended that the system be reinforced to handle all N-1 contingencies by adding 115 KV transmission lines to the substations feeding the Downtown area.

For the substations which at present are fed from a single 115 kV line, it is recommended that these substations are reinforced from a second 115 kV line to be able to ride through an N-1 contingency.

2.3.7 Distribution System

2.3.7.1 Scope

PSE is using a combination of 12.5 kV underground cables and overhead lines for the distribution of power to users via transformers that step down the voltage to a level that can be directly used by most power users. The objective of this task is to review the design assumptions for the power distribution system from reliability perspectives.

2.3.7.2 Distribution System Review

PSE utilizes a network of 12.5 kV conductors to route electric power around the City and to deliver power to its customers. The 12.5 kV power is delivered from electrical substations situated at various locations within and adjacent to Bellevue's city limits (see Figure 30). Each of these substations is fed from at least one 115 kV line, as previously discussed, and one or more transformers within each substation steps the voltage down to 12.5 kV for distribution within the City. Two different methods are used for distributing this power:

1. Overhead bare or covered conductors on utility poles
2. Underground cables directly buried in the earth or fed through conduits.

Some amount of redundancy is built into the PSE distribution system in Bellevue. For example, all of the distribution substations contain an auxiliary 12.5 kV bus that is available for use in the event that the main 12.5 kV bus becomes unavailable. In addition, transformer and feeder loading guidelines, as well as a network of distribution switches at various locations, allow for backup feeds to portions of the City affected by outages. Although this switching system is mostly manual at this time, requiring action by onsite personnel, PSE has implemented a program to replace older switches with newer-technology devices that will allow for more remote switching in high density load areas, allowing for faster power restoration after outages.

Nearly the entire distribution system in the City is capable of N-1 (single contingency) operation, meaning that power can be restored during the loss of one distribution line via switches in the system to provide alternate feeds to loads while system repairs are made. However, the Downtown area of the City presents its own challenges due to the density of PSE customers in this area. Figure 33 provides a geographic representation of the four distribution substations that feed the Downtown. The Clyde Hill, North Bellevue, Lochleven, and Center substations together supply essentially all of the electric power to this area. To increase the reliability of this crucial part of the City, PSE has installed a "reliability ring" that provides a redundant standby feed to Downtown loads, which can be used in case of faults on the primary circuit feeding the load. The ready availability of the ring allows for faster restoration of power in the event of an unplanned outage, along with the ability to provide alternate feeds during times of system maintenance or construction.

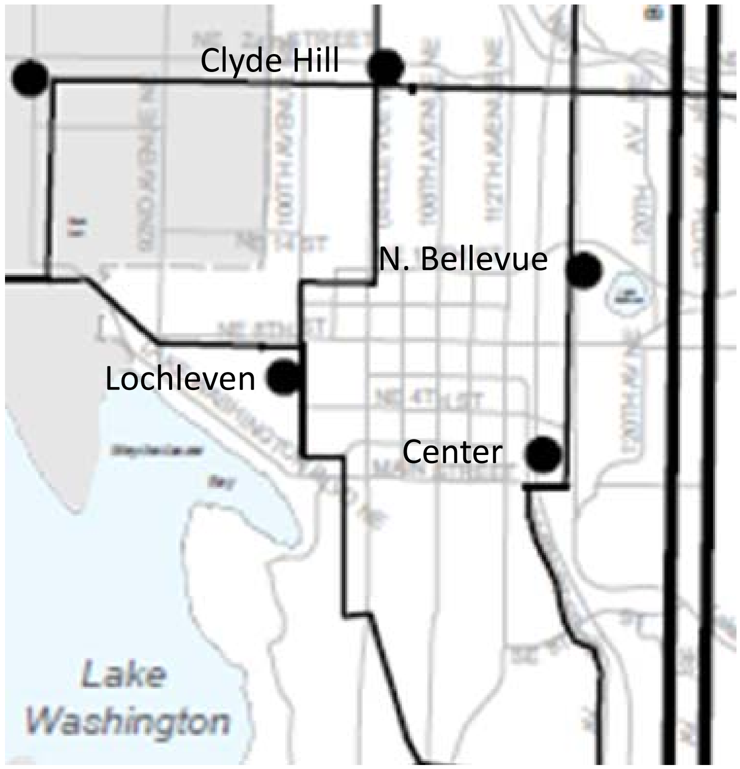

Figure 33. Downtown Substation Support

2.3.7.3 Distribution System Analysis

Overhead and underground distribution methods have distinct advantages and disadvantages. For example, installing overhead bare conductors on utility poles can be considerably less expensive than underground systems. However, overhead power distribution is not feasible for locations with the density of the City's Downtown area, which therefore is fed via underground cables. On one hand, overhead installations are generally subject to more frequent electrical faults and damage, especially from falling trees and tree limbs during storms and periods of gusty wind, from automobile accidents, and from animal contact. On the other hand, while underground conductors do not normally endure these problems (although occasional animal contact does happen), when underground electrical faults occur, the outage duration is often longer. One reason for this is that the fault locations are not readily observable so identification of an underground system fault is time consuming, and access to the fault location is typically difficult because of safety and physical access issues. Consequently, repair times are generally greater for underground cable systems than for overhead systems. This impacts the outage duration statistics.

While in general, underground systems should have fewer faults per circuit mile than overhead transmission circuits, they are often subjected to flooding of the vaults and workmanship issues related to joints or splices that can affect the reliability of the circuits. That is, underground systems are not as robust and forgiving as overhead circuits are. These issues are reflected in the actual failure statistics as discussed in Section 2.2.3.3.

2.3.7.4 Comparison to Other Utilities

Some older utilities use a low voltage network that typically operates at voltages that can be directly used by the power users. This means voltage levels at 480 V or 120/208 V. The load flows in these types of systems are not easily monitored and faults frequently lead to underground vault explosions since faults in cables of such a system will often burn free. In younger, modern cities, the power distribution is typically handled as it is done in Bellevue using 15 kV or higher class distribution cable systems, often with redundant feeder cables to supply the loads. In modern high rise buildings, 5 to 15 kV class substations are sometimes placed on many of the floors up through the building. Since PSE began to install underground cables a long time ago for the Downtown area, it does not have the redundant feeder cables often used for critical loads in newer cities. PSE has therefore installed a number of unloaded reliability circuits, which can be switched to feed power to customers affected by a cable outage. Thus, PSE's system design compares well with other cities with which Exponent is familiar.

2.3.7.5 Recommendations

- The City needs to decide how to approach conversion of overhead distribution lines, used primarily in the residential areas, to underground systems, which requires special funding mechanisms.
- PSE needs to continue to reinforce the distribution system to meet the N-1 criteria for the entire City.

2.3.8 PSE's Substation Designs

2.3.8.1 Transmission Substations

PSE has built, owns, and operates transmission substations operating with voltages up to 230 kV for its bulk power supply. These incorporate large power transformers, which are used to reduce the voltage for distribution of power at 115 kV. Most of the substations used for power infeeds to load areas contain transformers rated 25 MW that are used to reduce the voltage from 115 kV to 12.5 kV for power distribution using cables and overhead distribution lines. The power is then stepped down to voltage levels that can be used by PSE's customers by means of underground vault transformers, pad mount transformers placed aboveground, or pole top transformers placed on the distribution power poles close to residences.

The Sammamish North King substation is one of two bulk power substations feeding power into Bellevue. As is shown in Figure 34, bulk oil circuit breakers are used for switching of the 230 kV lines and buses. However, as can be seen in Figure 35, a sulfur hexafluoride (SF6) circuit breaker is used in one 230 kV breaker position. According to PSE, oil breakers are replaced by SF6 circuit breakers when the oil breakers are no longer maintainable or repairable if they fail. This can be expected to reduce the maintenance costs since oil breakers require frequent maintenance whereas SF6 breakers are almost maintenance free.[52] Figure 36 and Figure 37 show the same mixture of oil and SF6 breakers in the 115 kV switchyard at Sammamish as in the Lakeside switchyard.

IMG_1893 resized.jpg

Figure 34. 230 kV Switchyard with Bulk Oil Breakers at Sammamish Substation

52 Oil breakers generate an arc under oil when they interrupt currents. This degrades the oil. Also, the breakers are exposed to ambient air and will therefore absorb moisture, which also degrades the oil. Frequent oil testing is therefore necessary. If the oil quality is below minimum standards, it needs to be reprocessed or replaced. SF6 breakers are installed in a completely sealed tank and require only a minimum amount of testing and monitoring. Both types of breakers require inspection and possibly replacement of internal components after interrupting high level, long duration, short circuit currents.

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Figure 35. SF6 Circuit Breaker at Sammamish Substation

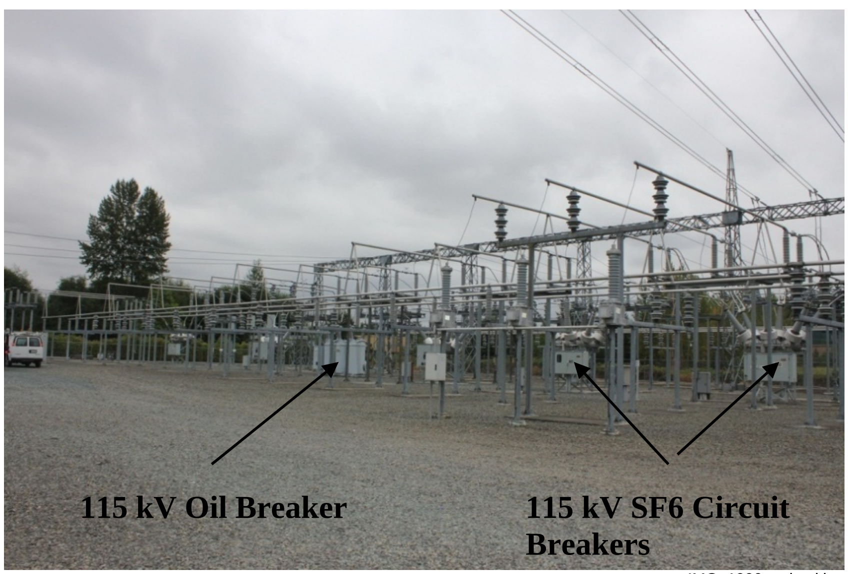

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Figure 36. 115 kV switchyard with a mixture of bulk oil and SF6 circuit breakers at Lakeside Substation

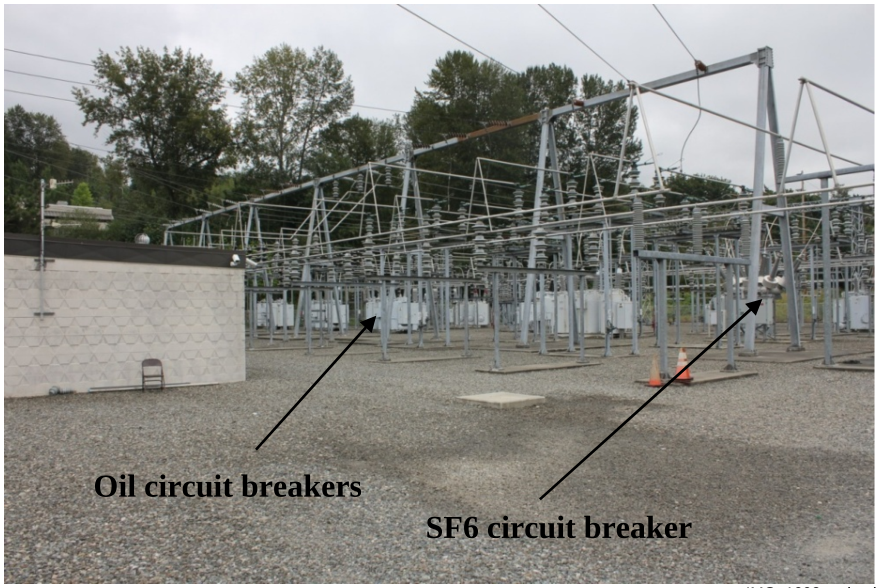

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Figure 37. Lakeside 115 kV switchyard

Figure 38 shows a new 325 MVA transformer that was installed a short time ago to replace a transformer that failed. The installed transformer was a spare that had been procured by PSE in case of a failure of a transformer of this type. Since PSE has established 325 MVA as the rated power for bulk 230/115 kV transformers, PSE is able to have one spare high power transformer to be used in case of any bulk power transformer failure. This enabled PSE to restore the Sammamish substation to normal operation in a short time after removing the failed transformer. It could have taken from 10 to 18 months to obtain a replacement transformer, during which time the station would have had to operate at reduced capacity. PSE demonstrated in this case that it pursues a prudent strategy of spare parts inventory. Figure 39 shows that the new transformer is equipped with an on-line gas-in-oil monitoring device, which should enable early detection of many incipient transformer failures, which should reduce the cost of future transformer repairs.

The Sammamish substation appears to be relatively well designed to survive at least moderate earthquake forces. The transformers are welded to the foundation and if the breakers are also welded or secured to their foundations, they should remain in place during an earthquake. The station for the most part uses equipment placed directly on ground level foundations, which reduces the risk of amplification of earthquake forces. One potentially weak point might be the attachment of the flexible connections shown in Figure 40, since some experience from other earthquakes has demonstrated that flexible conductors attached to the overhead structure by means of suspension insulators have failed and fallen down to the ground. However, in case of a severe earthquake, the power supply is not likely to remain after the event. But such damage would be easy to repair and if the equipment is not seriously damaged, it should be relatively easy to restore the power and to put the system back in operation.[53] An assessment of the dynamic forces on the suspension insulators caused by earthquake forces would possibly reduce the risk of damage to the substation and would be a prudent use of resources.

[53] Experience has shown that the transformer breakers will be tripped because of sudden pressure or Buchholtz relay operations from the transformer protections. However, if the transformers are not damaged by the earthquake forces, restoring power is a simple operation.

IMG_1894 resized.jpg

Figure 38. New 325 MVA Transformer at Sammamish Substation

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Figure 39. Transformer equipped with a modern on-line gas-in-oil monitor at Sammamish Substation

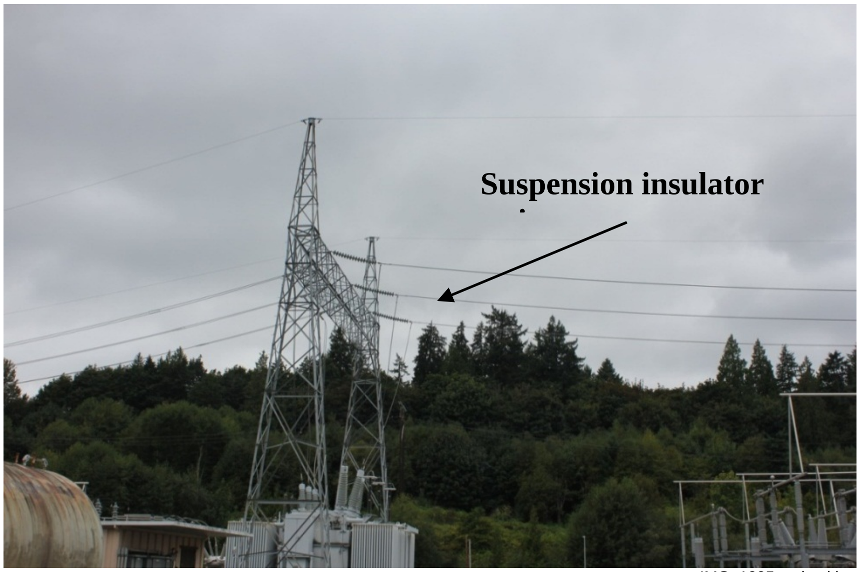

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Figure 40. Suspension insulator string that might be vulnerable in case of a major earthquake

Figure 41 shows a section of the protective relaying system racks in the Sammamish substation. It shows that PSE has installed newer, microprocessor-based, digital protective relaying equipment in the station. These types of relays record the data sample sets associated with power system disturbances, including information about output commands to open (trip) circuit breakers or to initiate other functions needed to isolate a fault on a line or in a piece of equipment. These types of relays also typically estimate the location of a fault, which enables the power system operators to dispatch crews to a location close to where the fault most likely occurred. After the event, the recorded information can also be used to assess if the protective relaying functions were executed properly, if the circuit breakers operated as they should have operated, and if the circuit breakers potentially suffered from high fault current duty requiring inspection of the breaker contacts. The information provided by digital protective relays has many uses that enable the utilities to assign resources more efficiently and to maintain equipment on a "just in time" basis, which should reduce the operating costs for the utility that uses such equipment. Figure 42 shows that digital protective relays are also installed in older switching and substations as a retrofit or upgrade of the protective relaying systems. Figure 43 shows the human interface panel connected to the SCADA remote unit in the substation. This piece of equipment enables the operators to control the equipment in the substation locally. All of this is evidence that PSE is pursuing a strategy of gradual upgrading of its aging infrastructure.

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Figure 41. Digital protective relaying installed in the Sammamish substation

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Figure 42. Digital relay retrofit in the Lakeside switching station

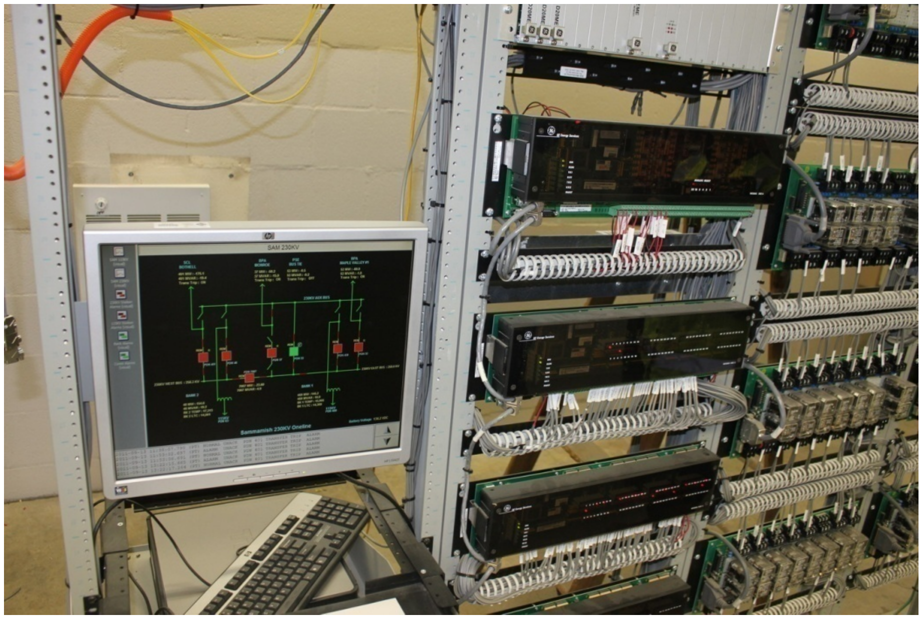

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Figure 43. SCADA system and control panel for the Sammamish substation

Figure 44 shows the high voltage, 115 kV side of the Factoria substation. In this substation, new, gas-insulated substation equipment has been installed for the 115 kV side switching equipment, which is saving space but also to some degree, reduces the probability of a falling tree branch causing a short circuit that leads to loss of power feeding the loads that are supposed to be fed from this substation. This substation also has metal clad switchgear installed for a portion of the 12.5 kV distribution system. This also reduces the probability for tree branch-induced faults to the 12.5 kV distribution circuits inside the substation. As can be seen in Figure 45, the open air distribution switchgear racks includes a number of animal guards primarily intended to prevent squirrels form climbing up into the switchgear and causing outages. Such guards or shields should help improve the reliability of the power system even though other wildlife induced outages are still probable. However, as shown in Figure 46, outages are probably more common along distribution lines than in transmission substations. [54]

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[54] The birds survived at least this time.

IMG_1921 resized.jpg

Figure 44. Factoria Substation

IMG_1922 resized.jpg

Figure 45. 15 kV Open Air & Metal Clad Switchgear in Factoria Substation

IMG_0891 cropped.jpg

Figure 46. Turkey Buzzards Perched on Top of a 15 kV Distribution Pole and Transformer

2.3.8.2 Distribution Substations

A typical distribution substation contains one or two 25 MVA power transformers, and to help ensure long transformer life, PSE has established operating guidelines that dictate the maximum power loading of these transformers under both winter and summer conditions. The guidelines are based on existing IEEE standards and available information from other utilities and substation transformer manufacturers, and are used as both a power loading maximum and asset management tool to allow system planners to effectively manage the equipment and plan for system upgrades. These maximum loadings take into account the ambient temperature, which affects the amount of power the transformers can safely handle without an expected reduction in lifespan. The maximum loading values must account for the configuration of the system at a given time. Thus, for N-0 (normal) operating conditions, a continuous power flow maximum is specified, while for an N-1 condition (where a distribution transformer must supply some portion of another transformer's normal load), a larger, short-term power rating is allowed. PSE's proper adherence to maximum transformer loading criteria is essential to asset management and also to overall system reliability.

In a similar way, maximum power loading values for individual 12.5 kV distribution feeder circuits are specified. A typical feeder circuit on PSE's Bellevue system consists of a looped feed such that a circuit breaker from one substation normally feeds certain loads, but those loads can receive an alternate (normally open) feed from another circuit breaker in the event of a loss of the normal feed. This capability increases the overall reliability of the distribution system, and is made possible through the use of manual switches on the distribution system located throughout the City. In the event that such an N-1 condition exists (such as a faulted distribution line), an individual feeder circuit could be called upon to deliver more than its usual power, since it must temporarily feed its own normal loads plus some portion of loads normally fed from another source. PSE feeder loading guidelines require no more than 83% loading of feeders in the N-0 condition but do allow for temporary 100% feeder loading during N-1 conditions.

Roughly half of PSE's distribution conductors within Bellevue are installed underground. Due to the inherent difficulties associated with locating underground faults and subsequent repairs, PSE has enacted several proactive projects to help reduce the number of unplanned outages caused by underground cable and equipment. For example, older, failure-prone underground oil-filled switches are being replaced with more robust S&C Vista SF6 switches, especially in the busy Downtown area. PSE is addressing its aging population of underground cables (some installed as early as 1965). Some of the older underground cable installations use unjacketed, concentric neutral high molecular weight polyethylene directly-buried cable, which has experienced a high failure rate. PSE replaces these cables when they are found to be in poor condition.

In locations where underground cable replacement is particularly costly, a program that uses injection of silicon into the cables has been implemented as a preventive, cable life-extension measure. Since PSE recognizes the potential vulnerability to having cables from multiple circuits in the same underground vaults, ongoing projects are underway to relocate underground cables such that underground vaults contain cables from no more than two circuits. Underground installations often make use of self-contained underground service transformers, which have a high risk of failure as they age. PSE replaces these transformers when they are found to be in poor condition (or when associated bayonet fuses blow or fail) with aboveground pad-mounted transformers, where possible, or direct underground replacement with stainless-steel tank enclosed transformers.

Overhead conductors also present special challenges. Due to the large number of tall trees in Bellevue, the overhead distribution system is subject to electrical faults from falling tree limbs and occasionally entire trees. PSE's vegetation management program normally addresses these issues, but in some areas vegetation management restrictions prevent more comprehensive removal of limbs that threaten the lines. Whereas these types of faults are normally short duration events, PSE has installed covered conductors (tree wire) in areas where vegetation management restrictions prevent more comprehensive removal of limbs that threaten the lines.[55] Animal contact with high-voltage lines is also an ongoing concern, similar to the situation within substations, where buswork and other live parts are frequented by squirrels, birds, and other animals. To reduce the incidents of animal contact with live overhead conductors, animal guards have been added where the original equipment design has been deemed ineffective (see Figure 45 and Figure 47) and newer equipment, such as transformers, comes equipped with animal guards.

55 The insulation of these tree wire conductors do, however, reduce the probability that fuses will operate in case such a wire falls down on the ground. Tree wires reduce the number of faults resulting from contacts between a tree branch and a line. However, a broken tree wire on the ground represents an electrocution hazard but at the same time it must be recognized that all wires on the ground can be an electrocution hazard.

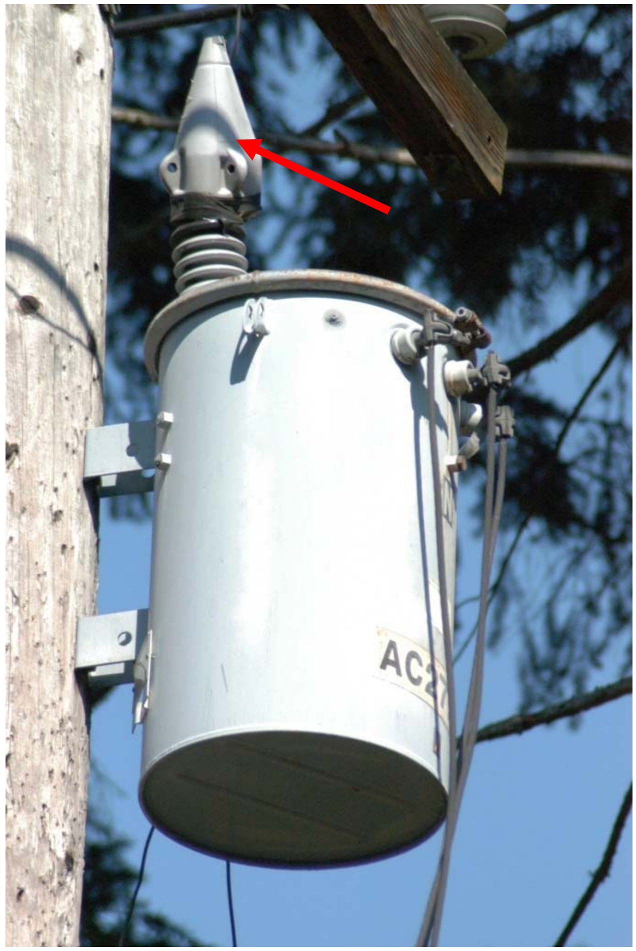

Figure 47. Use of an animal guard (arrow) to prevent inadvertent contact at the top of an overhead service transformer

While the transmission system uses SCADA systems for monitoring and control for its daily operations, nearly all of the PSE distribution system in Bellevue uses SCADA for monitoring only, this is mostly within the distribution substations. From both a reliability and outage restoration perspective, SCADA can be used to more quickly isolate distribution system problems and to remotely switch portions of the system that are affected, allowing power to be restored to customers more quickly.

PSE projects are addressing this enhanced functionality on two fronts. First, a pilot project is being planned that will enable several field distribution switches in the Downtown area to communicate load data to the SCADA system, while providing the capability of remote SCADA operation of those switches for system sectionalizing. Once the remote equipment modifications are made, another phase of the project will introduce automatic switching logic at select locations, such that switching and restoration decisions can be made faster. The current plan is to do this type of upgrade on several switches a year for the next few years.

2.3.9 System Design Summary

The results of the system design assessment are summarized below with a list of findings and observations, a discussion of potential actions, and a list of recommendations.

2.3.9.1 Findings and Observations

Key findings and observations are:

- Reliability is impacted by the design of the distribution system within the City. The design of the system to provide redundancy through multiple sources (substations) to each circuit provides for faster recovery times from outages through the ability to switch power from one source to another. There remains a need within the City to improve the overall redundancy in the City, such as:
  - Completing and maintaining the reliability ring in the Downtown area to provide additional backup sources of power
  - Providing additional substation feeds to radial circuits outside of the Downtown (e.g., Phantom Lake and Lake Hills)
  - Provide switches and ties to distribution circuits to provide additional feeds to isolated circuits.
- Distribution automation is not yet utilized throughout the system. Installation of switches with SCADA, reclosers on overhead lines, and fully automated substations provides an opportunity to improve overall system reliability through better control and response to events on the system.
- Upgraded equipment is being installed at transmission substations. These equipment items represent more current technology, provide for hardening of the substations through reduced maintenance, and they are less susceptible to external events.

Potential actions to improve system reliability through system design are discussed below.

2.3.9.2 Industry Practice

Most distribution systems are radial systems with a main feeder coming from a substation. Lateral branches or taps come off the main feeder to supply power to customers. For conditions requiring additional reliability, looped radial systems are used which allow for redundancy by providing the ability to switch power sources in the event of an outage to provide faster recovery. The switching is typically performed by onsite manual operation of the switches. The looped system provides higher reliability than radial systems resulting in limited long-duration outages.

Major industry developments for reliability from a distribution design perspective are:

- As described above, the use of looped radial or network systems to improve system redundancy. This design configuration provides a means for faster restoration when an outage occurs because backup feeds are available to supply power after switching (manual or automatic).
- The use of SCADA to allow for remotely-controlled (or automatic) switches and reclosers to provide faster response to faults and to reduce the duration of outages.
- Redistribution of circuit loads to allow for effective use of multiple transformer banks and to allow for effective switching during a circuit outage. This again provides a means to restore power to a circuit in the event of an outage.
- When replacing failed or aging equipment, the use of current technology provides a means to reduce equipment failure and reduce maintenance costs. Currently technology deployments include:
  - Gas-insulated substations are more compact and require less space for installation, result in reduced maintenance, and are less susceptible to external events.
  - SF6 breakers (to replace oil-filled circuit breakers) reduce environmental impacts of potential oil spills, are more compact, and require less maintenance.
  - Microprocessor-based protection relays provide better communication and data capture to evaluate events on the system and to respond to regulatory requirements.
  - Metal clad switchgear for distribution stations
  - On-line monitoring of substation equipment to improve maintenance and find problems before they occur.

  The key benefits of these new equipment features are to minimize equipment failure.

The majority of the current Bellevue system is served by a looped radial system to allow for multiple sources of power. However, much of the system is served by manual switches. PSE has:

- Ongoing projects to fully loop the Bellevue system and is increasing the use of switches and feeder ties to provide for the ability to supply power to circuits from alternate sources.
- Ongoing projects to increase the installation of reclosers to minimize recovery from faults.

- Longer-range plans to improve overall automation of the system (both DMS and SCADA within the system).

Exponent concurs with the actions being conducted by PSE. These actions are consistent with maintaining and improving reliability of the Bellevue system. These actions are intended to provide additional redundancy in the Bellevue system and the equipment upgrades are accepted industry practice to improving reliability.

2.3.9.3 Recommendations

Based on the system design assessment, the following recommendations are made to improve the City's ability to be a more proactive participant in improving reliability:

- Similar to recommendations from the outage review, the City should meet with PSE on an annual basis to understand what projects are being identified and scheduled each year with the specific goal of improved reliability including system design improvements.
- PSE should continue with its implementation of current programs designed to improve overall system reliability in the City, including:
  - Continuation of system hardening projects.
  - Installation and implementation of distribution automation.

The remainder of the section provides a discussion of the work processes relative to the potential for reliability risk.

2.4 Review of PSE Work Practices

2.4.1 Scope

The outage assessment and review of the PSE system design provide input into issues that may impact system reliability. This section provides a review of the work processes that utilities use to address system expansion, aging, and reliability issues. These work processes include design practices, maintenance, capital work prioritization, vegetation management, and outage management.

2.4.2 Study Approach

PSE made personnel and information accessible to describe these various programs and to allow assessment of these programs relative to reliability in Bellevue. The review of the work processes was performed to allow for assessment of these work practices as they impact system reliability.

2.4.3 Maintenance Practices Review

Distribution maintenance processes are evolving in the industry. The typical maintenance practice for distribution assets was to run-to-failure since there is a large amount of equipment and it is relatively inexpensive and easy to replace. Additionally, there was limited automation on distribution systems so that there was limited opportunity to do on-line or remote monitoring. As the industry has evolved, maintenance practices have advanced relative to distribution assets.

PSE has implemented a maintenance program that includes the following attributes:

- Annual review of the maintenance plans based on equipment types
- Scheduling and work management of maintenance tasks in the Systems Analysis and Program Development (SAP) system
- Procedures available for all equipment on company intranet
- Ongoing review of maintenance and standards by intercompany team.

The maintenance program is reviewed annually as part of the annual budget process to define or confirm maintenance and inspection plans. A team of engineering, planning, and maintenance personnel perform ongoing reviews of the program and make recommendations for changes to work standards and maintenance requirements. A description of the maintenance process is provided based on a discussion with PSE personnel and a review of the substation maintenance standards.

2.4.3.1 Maintenance Plans

Equipment and outage trends are reviewed and provide the basis of the annual plans. Based on current performance or other issues raised during the review, PSE prepares the maintenance plan. From a practical perspective, the annual plan consists of standing maintenance and inspection tasks which are modified based on equipment performance. The maintenance plan is divided into two specific areas:

- Substation equipment (which consists of all equipment inside the substation fence plus batteries)
- Distribution line equipment.

Currently, there are no Bellevue-specific maintenance programs relative to equipment items. The current maintenance programs apply system-wide. These programs are discussed below

There are approximately 400 substations in the PSE system. PSE personnel maintain and inspect the substations. Maintenance crews and inspectors are assigned to various areas within the PSE system and are responsible for performing the defined maintenance tasks. From a substation perspective, the following maintenance programs are defined:

- Monthly substation walk-through of distribution substations by inspectors. The inspectors collect substation equipment readings and review the general condition of the substation. These inspectors are capable of switching operations if necessary.

- Transformer maintenance and inspection performed by substation crews:

  - 6-month oil dissolved gas analysis
  - 3-year oil physical test
  - 6-month maintenance of load tap changers
  - 12-month overall transformer maintenance.

  There is a program to provide on-line monitoring of all of the transmission transformers, but there are no current plans for the distribution substations.

- Circuit breaker maintenance and inspection performed by substation crews:

  - Although oil-filled circuit breakers are being replaced, frequent tests of the oil quality are still needed and are performed
  - Mechanism tests on circuit breakers at defined intervals.

- Substation infrared scans are performed every 2 years to identify any potential problem areas.

- Prioritized program for replacement of banks based on age profile of the assets. There are very few outages each year associated with substation equipment failures. However, the prioritized program is replacing about five transformers per year. This program is aimed at the banks that were installed in the 1970s time frame. The purpose of this program is to proactively replace banks prior to failure.

Based on the substation outage performance, the maintenance program for substations is assisting PSE in maintaining system reliability. Substation outages have the potential to impact a large number of customers but PSE's program has been effective in minimizing substation impacts on system reliability.

PSE implements a maintenance strategy for distribution line equipment that includes inspection of some assets and run-to-failure for other assets. The distribution maintenance programs include the following:

- Pole inspections (test and treat) are performed on a 15-year cycle (distribution) and consist of visual inspection and other tests as required by PSE standards

- A pilot program is being evaluated for performing partial discharge testing of underground cable to determine if this methodology will be effective in identifying potential cable problems
- Equipment items, such as switches, regulators, reclosers, and line transformers are identified as run-to-failure components.

The distribution line maintenance is also supplemented by general infrared inspections that are intended to identify problems and eliminate potential future failures. However, this general inspection is utilized on an as-needed basis.

2.4.3.2 Comparison between PSE and Other Utilities

The overall maintenance strategies employed by PSE are consistent with industry practices for transmission and in most respects also for distribution equipment. PSE employs corrective maintenance (run-to-failure); time-based maintenance and replacement for some assets (poles, banks, breakers); and predictive (condition-based monitoring) for more critical elements, such as transformers. However, some utilities have developed methods for replacing distribution transformers, such as those placed at the top of power poles based on the total energy consumed by the connected loads. The assumption is that the total energy supplied through a specific transformer is an indication of the peak load carried by the transformer, which is an indicator of the operating temperature of the transformer. Since transformers operating hot are likely to fail early, transformers carrying heavy loads are moved out and replaced by a higher capacity transformer. Such practices could avoid some transformer failures and improve the reliability of the system.

2.4.3.3 Maintenance Work Management

PSE utilizes the SAP system for scheduling and work management. All maintenance tasks are entered in the SAP system and assigned due dates. The work management process for maintenance is performed in the following steps:

- The SAP system provides a monthly list of work orders by the 15^{th} day of the month prior to the required task.
- These orders are assigned to crews by the maintenance supervisors, who then plan for performing the task.
- The crew completes the defined maintenance tasks within the defined month.
- The completed work order is reviewed by the maintenance supervisor and by substation operations coordinator, who closes the order.
- The maintenance documentation is then sent for engineering review and submitted to records storage.
- There is a biweekly work coordination meeting to identify any changes to the work plan. Operations requirements, clearances, and unplanned maintenance

may require modifications to the schedule, this meeting is intended to address changes. PSE also utilizes standing work orders for routine tasks.

The maintenance and inspection crews are originally scheduled for about 60% planned work, which allows time for responding to corrective maintenance and other tasks.

2.4.3.4 Comparison between PSE and Other Utilities

The industry uses maintenance programs that include defined maintenance tasks for equipment items that consist of a range of maintenance tasks from run-to-failure and corrective maintenance to preventive maintenance (time-based tasks) to preventive maintenance (condition-monitored). These tasks are then incorporated into a computerized maintenance management system that provides for timely scheduling and close-out of tasks. The overall maintenance program is reviewed on a regular basis to allow improvements and changes to the maintenance program.

The use of SAP or similar programs is an industry standard for maintenance management. Many large utilities use this type of program to identify, schedule, and track maintenance tasks.

2.4.3.5 Maintenance Process Analysis

The maintenance program supports the overall reliability of the electric system. Utilities that are leaders in maintenance practice incorporate an approach that defines the maintenance strategy for equipment types, reviews equipment performance to modify the strategy, and implements an effective work management program. PSE appears to perform its maintenance program well. No obvious areas for improvements have been identified except to explore the use of total metered energy to indicate timely replacement of distribution transformers.

PSE has a well-defined strategy for substation assets and based on the outage review and the overall system design, there are limited outages in Bellevue from substation events. Therefore, the PSE strategy relative to substations is effective in supporting substation reliability.

The distribution line outages are mostly related to underground cables and overhead conductors. There is currently limited ability to perform maintenance on lines. Periodic inspection (through use of infrared or other technique) may be beneficial in identifying potential failures before they occur; however, this has limited use due to the large number of distribution assets and difficulties associated with interpretation of infrared diagnostic data.

2.4.4 Capital Project Prioritization

2.4.4.1 Scope

Capital investments made by utilities most likely lead to increased rates charged for the electric power but can also be beneficial in improving the reliability of the power system. Utilities define capital projects in response to various business drivers, such as new capacity or expansions, asset replacement, reliability initiatives, regulatory requirements, and compliance needs. Industry-leading capital project prioritization programs provide a standard and consistent set of decision parameters to define and prioritize projects within an organization. The list of prioritized projects is then matched with budget and resource constraints.

2.4.4.2 Study Approach

PSE made personnel and information accessible to describe these various capital improvement projects and the process used to select projects for implementation. The review of the work processes was performed to allow for assessment of these work practices as they impact system reliability.

2.4.4.3 Prioritization Process

PSE utilizes the following criteria in determining infrastructure assessment as stated in their IRP:

- Load growth
- Reliability
- Regulatory compliance
- Aging infrastructure
- External commitment
- Integration of resources.

PSE has a capital project tool (IDOT) that is used for all proposed projects. Projects are typically proposed by the transmission and distribution (T&D) planners for the electric system, but all PSE capital projects are entered into the IDOT system. The requirement for entry into IDOT is that a proposed project has a scope of work, proposed budget, and evaluation against a standard set of criteria. The projects are entered into IDOT and receive an IDOT priority number. This process places the project in a prioritized list against all other projects. If the project makes the cut relative to budget and resources, then the project is appropriately scheduled. If a project does not make the cut, the project remains on the list and gets updated for the next review period. PSE typically performs the capital project assessment with the annual budget cycle, but projects are reviewed on a monthly basis.

2.4.4.4 Capital Project Review

PSE planners are assigned specific areas in the PSE system. The planners are responsible for reviewing the performance of the distribution circuits and recommending projects for consideration in the capital project prioritization process. Given the slow growth over the past few years, there is limited need for capacity additions and reliability programs have gained higher priority. PSE has established the following programs that contribute to improved system reliability across the PSE system:

- **Reliability Initiative:** This program addresses the addition of reclosers into the system to provide for automatic re-energizing of lines when a fault on the line occurs. The recloser will automatically reclose into the fault and if the line holds, the fault is gone. Reclosers might make several attempts to clear the line. This reduces the restoration time since crews are not required to manually re-energize the line.

- **Bellevue Reliability Program:** This program exists to reinforce the Downtown area of Bellevue. Since this area is one of the densest areas of the PSE system, this reliability program exists to enhance the redundancy and reliability of the Downtown system.

- **Underground Cable Remediation Program:** This program is a system-wide program to address older cable. The program consists of remediation (silicon injection) to extend the life of the cable and cable replacement (cable older than 30 years). There has been an ongoing effort to replace underground cable in Bellevue to address reliability concerns.

- **Aging Asset Replacement:** This program is aimed at proactively replacing aging equipment assets, and in Bellevue is primarily aimed at replacing older switches.

- **Overhead Conductor Tree Wire:** This program is aimed at areas that have significant numbers of overhead line outages due to tree-related events. The use of tree wire is intended to reduce the potential for faults (and outages) from tree branch contact with overhead wires. The tree wire is a covered conductor so that it does not create a fault upon contact with a branch. The tree wire is also stronger so that it can resist some tree branch impacts.

- **Distribution Automation:** The use of automation in distribution systems is increasing and companies are investing in distribution automation to improve reliability. PSE is undertaking a program to install distribution substation automation to improve distribution system visibility and to allow for a basic level of control by the operators.

In addition to these system-wide programs, PSE also reviews circuits of concern and proposes specific projects to address these issues. Over the past 5 years, PSE has performed or is in the process of performing about 80 capital improvement projects in Bellevue. These projects include 20 projects related to reliability outside the Downtown area and 20 projects in the Downtown area. These projects were specifically designated as reliability projects and include projects such as tree wire installations, feeder and switch replacement, feeder ties, and reinforcement of the Downtown circuits. These projects are intended to address issues identified on circuits in Bellevue and to provide for improved reliability.

2.4.4.5 Comparison between PSE and Other Utilities

Prioritization and selection of capital projects are normally evaluated in the industry against a defined set of criteria consistent with the utility's goals. These criteria apply to all projects and are used to guide decision-making around budgeting and scheduling of projects. Management of the capital program also requires ongoing evaluation of new project requests against the standard criteria and decisions to adjust the portfolio of projects, as required.

PSE has employed a consistent approach to project prioritization. This system is used for all company capital projects, gets a significant management review, and represents a good industry practice.

2.4.4.6 Capital Project Process Analysis

The capital projects identified in Bellevue have very specific impacts on system reliability. While many of the projects are related to aging asset replacement, these projects (over the past 5 years) are specifically identified as addressing reliability in Bellevue. These projects are part of the system-wide upgrades, as well as circuit-specific improvements. As identified in the outage analysis and system review, there are several concerns being addressed by the capital projects:

- Underground cable failures (cable replacement and remediation)
- Tree-related outages (tree wire)
- System reinforcement (completion of the Downtown reliability loop and feeder ties to improve performance on radial lines)
- System restoration (SCADA, reclosers).

Many utilities are now focusing on initiatives related to underground cable remediation and distribution automation. As reliability improvement is being required, utility initiatives related to reliability are receiving favorable rate case reviews and dispositions.

2.4.5 Vegetation Management

2.4.5.1 Scope

Vegetation management is a major issue relative to the reliability of Bellevue's overhead system.

2.4.5.2 Approach

PSE made personnel and information accessible for the review of the vegetation management process. In addition, some areas in the City were inspected on foot.

2.4.5.3 Vegetation Management Review

The environment in the City with its tall and dense trees is a valued treasure to the City and its citizens. However, this environment places a stress on the overhead system assets. The interaction of tree limbs and branches with electric wires creates faults which may develop into outages.

From a reliability perspective, the impacts of tree and weather events on the overhead system require attention. Selected use of tree wire to preclude faults and the ability to utilize reclosers and automation to limit outage durations will provide some increased overhead reliability.

PSE utilizes a 4-year cycle to trim trees. It also implements programs to identify at-risk trees and provide alternatives when trees need to be removed. The City, however, has restrictive rules regarding tree maintenance as defined in the Franchise Agreement, which sets the limits for what PSE can do.

2.4.5.4 Vegetation Management Analysis

There is a natural conflict between the desire to have large and beautiful trees in the neighborhoods and to have reliable electric power delivery. It is really a choice between one or the other, since the goals are incompatible. The rules for vegetation management are under the control of the City and therefore, any changes will have to begin by changing the City's ordinance related to vegetation control.

Undergrounding of the distribution circuits is an option if a formula for how to obtain financing for such an investment can be found. However, even underground systems, as can be seen from the reliability statistics presented above, do not remove all of the reliability problems but it would reduce those outages caused by trees or tree limbs. The requirements for underground conversions were discussed earlier in Section 2.2.6.4.

2.4.6 PSE's Operations Centers

2.4.6.1 Scope

PSE is currently installing and implementing a major change to its system information technology. The current projects include an integrated system to upgrade the systems for geographic information management, customer management, outage management, and distribution management. This effort is a major, multi-year initiative to upgrade and modernize their utility information architecture and systems. The upgrade of the information technology systems is a major step to improving reliability now and in the future.

This review covered a review of the existing systems used for operation and control of the system as well as a look at the plans and states of the development of the new systems used for power generation dispatching systems, power delivery systems for T&D of electric power, as well as dispatching people to perform operations in the field and repairs of equipment. The review also included systems available for management of major events that can be classified as emergencies.

2.4.6.2 Approach

PSE made personnel and information accessible for the review of its operations centers. This included the Emergency Operations Centers (EOCs), storm centers, dispatch center, and load center. A visit arranged to review the center facilities and operations was also included. This review also included a review of the KEMA Consulting Company (KEMA) report prepared after the 2006 storm event.

2.4.6.3 Emergency Operations Center Review

If a major storm is forecasted or other emergencies arise, PSE will staff one of its EOC.[56] The EOC is opened up for operation if there are reasons to believe that an approaching storm could be expected to cause widespread outages. It is also staffed if an event such as an earthquake or other non-predictable event were to occur and cause major power system damages. The main EOC is located in the same building as PSE's main power system control center.

The EOC is equipped with computer and communication systems that will give the PSE managers, charged with management of the emergency, the visibility of the situation needed to direct PSE's resources required for handling the event. It has links to outside agencies and news media with which PSE has to interact. This includes links (mostly telephone links) to county and city EOCs. The staffing in PSE's EOC includes the following:

- PSE managers for:
  - Crew dispatching
  - Resource allocation
- Communication people from PSE
- News media
- PSE's control center.

The centers are also staffed for training purposes to ensure that the people required to be at the centers know how to perform their assigned duties. The staffing is rotated among PSE's management personnel such that there will always be trained people available to staff the centers at any time (day or night) of the week.

The EOC is being upgraded with systems connected to the control center. A display providing minute-to-minute information about the electric power transmission system has been added.

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56 PSE has one EOC and one backup EOC in case the main EOC becomes unavailable or is inaccessible.

2.4.6.4 Storm Center Review

PSE dispatches crews to assess the damages and for repair of damaged systems or components from so called storm centers. These centers are basically paper-driven with large map boards for tracking failure reports and crew assignments. Although this seems to be an "old fashioned" approach, it is inherently a rugged system that can operate almost without any complex support systems for as long as telephone and radios are operational. At the center that was visited, a large amount of spare parts and materials needed for repair of lines and cables was also available.[57] That is, the storm center design seems appropriate for the situations facing PSE.

2.4.6.5 Outage and Distribution System Management Review

PSE utilizes software tools to help track outages, customer feedback, and maintenance tasks. Customer relations management software known as ConsumerLinX (CLX) is used to log customer-reported outages and other feedback, similar to a conventional customer contact center, but with the added advantage of a networked system. Use of the tool allows many individuals within the PSE organization to be aware of the latest reported outages and for the correct response to be undertaken (send evaluation personnel, alert maintenance crews, etc.). Calls are still received by a reception person who then enters the information manually into CLX, which can then be queried by appropriate individuals as needed. Additionally, PSE uses another software tool called SAP to track maintenance tasks, parts inventory, and repair status. Generally speaking, CLX is used for customer-originated information and SAP is used for PSE-originated information. Only limited communication and data sharing is possible between the two systems. Furthermore, support for the CLX has become expensive, making the system difficult to maintain.

Today, the outage management system relies on communication from the customer regarding an outage and an onsite review (or call backs) by PSE personnel to confirm that power is restored. There is limited ability to use the automated meters installed throughout Bellevue to identify the location of outages and to ensure restoration. However, a review of the CLX system shows a quasi-real time system that has the ability to provide timely information to customers. All customer contacts are recorded and included in the CLX database. PSE office and field personnel also have the ability to update the CLX tool so that status of outages can be obtained. Therefore, even though PSE can obtain status of outages, the outward communication of status is limited. The current system does not provide for web access updates for outage events so the only means of tracking outage status is through calls into the utility. The inability to access updated status information has been raised as an issue during the stakeholder review.

In the event of a major outage, this system may get overwhelmed with the volume of information. The ability to provide timely status updates and communication with customers is very difficult.

[57] Concentrated storage of unsecured spare parts would not be recommended in areas that could be impacted by severe earthquakes. Although this is possible in the northwest, the most likely severe event would be a repeat of the 2006 storm, in which case the spare parts depot would probably not be seriously impacted.

PSE is planning a series of upgrades that will address not only the shortcomings of the legacy CLX, but add new and important functionality as well. The new systems will benefit both the electric and gas portions of PSE's business. These upgrades are driven by the following objectives, as stated by PSE:

- Through improved ability to track customer data and maintain and utilize electric/natural gas infrastructure data, PSE will be able to more efficiently perform system maintenance
- PSE will be able to restore customer power in a more timely manner by targeting where the electric outage is within the network
- The new systems will allow PSE to proactively provide more detailed communications to our customers during power outages
- Improve PSE's ability to deliver better customer service by providing more accurate information.

2.4.6.6 Outage Management System Upgrade Review

The KEMA report concerning the 2006 storm event contained recommendations for an improved Outage Management System (OMS). As a result of this, PSE selected General Electric's (GE) Smallworld™ platform for its new OMS for both gas and electric systems.[58] PSE has also purchased a new EMS.

A geographic information system (GIS) will be connected to the new EMS. It will be used both for the gas and for the backbone electric systems to support OMS. However, it has been found necessary to do 100% field audits to establish circuit-by-circuit connectivity to get details such as phasing information correct. This is a time-consuming, but necessary process. The rollout of the GIS portion is expected to begin early 2012. The system is expected to be fully completed by 2017, but portions of the system are being rolled out as soon as they are ready. However, as discussed below, there are limits on how much power restoration can be improved by means of better information technology systems.

2.4.6.6.1 Outage Management Process

2.4.6.6.1.1 Tree Fault Sequence of Events

If a tree branch or a tree falls and causes an overhead distribution line fault, the fault might trigger fault detection systems that will open (remove power from) the circuit, followed a short time later by automatically reapplying power to the circuit. A momentary tree branch contact or an animal that might have caused the fault might no longer make contact with the line or might have caused fuses to melt as a result of an overcurrent caused by the fault, in which case the power will be restored automatically to some part of or the entire affected circuit.

[58] Reference 13.

If the first attempt to restore power is unsuccessful, additional attempts will typically be made with a longer time between the time the circuit was opened and the power is reapplied. If none of the automatic power restoration attempts are successful, the process will stop and the circuit will remain open. Such faults can be detected by reports from the automatic meter readers (AMR) installed in PSE's system reporting a loss of power or by someone calling into PSE reporting the outage.

2.4.6.6.1.2 Present Fault Identification and Repair Processes

At present PSE is primarily relying on phone calls to obtain outage information even though all of the meters connected to the affected circuit should have reported the outage. The AMR system information will only give information about the loss of power when it first happened but the callers might provide additional information about where the fault is located and the nature of the fault. However, if additional tree branches or trees fall on other parts of the line, such information will only be received from callers, who provide additional information. Especially, during a storm-related event, multiple tree-related damages to the overhead lines have to be considered.

In case of a permanent outage, there is no alternative for PSE but to send a qualified person out to inspect the damage or damages. This person will be able to determine the nature of the damage and provide information to the repair crews needed to identify what resources will be needed for the repair. The person sent to inspect the damage can also operate switches to isolate the faulted area and restore power to the parts of the circuit that are undamaged. However, the area served by the damaged part of the distribution circuit will be without power until the repair has been completed.

2.4.6.6.1.3 New Information Technology Aspects

Installation of additional control systems, automation and information gathering equipment, in the power system will reduce the time between the occurrence of the fault and the restoration of power to unaffected circuits. The added information provided by these systems will enable the fault location to be more precisely identified by means of fault location features installed in the monitoring equipment. Manually executed commends to operate switches from a remotely located operating center can be used to isolate the fault region and to restore power to the unfaulted regions. The rest of the process, including the inspection of the damages and the dispatching of repair crews as described above, must still take place.

2.4.6.6.1.4 Severe Storm Events

A severe storm, even such as the one experienced in 2006, poses several additional problems that have to be addressed. The first of these being that the amount of reported damages is reaching a level where resources are not available for the initial inspections that are needed to identify what needs to be repaired. The second is that if the power is lost to the 115 kV substations, there will be no information coming from the monitoring systems since these systems depend on recording voltage and current excursions from normal values to identify faults. In this situation, PSE would have to send out inspectors to identify where faults have occurred and where repair is needed. Automatic restoration of power or even manually initiated power restoration sometime after the initial power restoration attempts described above, would be hazardous to people and could not be attempted until the circuits had been inspected since the risk of electrocuting people close to downed conductors would be too great if such faults were not first eliminated.

During severe storm events, such as the one that affected Bellevue in 2006, PSE will be facing additional logistics problems. There is a limited number of qualified inspectors to make the damage assessments, and a limited number of repair crews readily available to perform the work. In addition, there will probably be a lack of spare parts, including a limited supply of the conductor material needed for the repair. While PSE has access to repair crews from outside the area and also access to spare parts and material from utilities located in other areas, the time to get crews and materials in place and working to restore power in Bellevue, would be significant.

2.4.6.6.1.5 Downed Conductor Hazards

Downed conductors represent a real hazard to people because such faults might not melt fuses to isolate the fault or might not open circuit breakers to remove power from the affected circuit under all conditions. There is no technology available to detect such faults with 100% certainty so a conductor in contact with ground always has to be considered as live; that is energized, until proven otherwise. Therefore, there is a limit to how much the outage duration can be reduced by installing additional monitoring systems and automation. Manual inspections are still needed to keep people safe.

2.4.6.7 Distribution Management System Upgrade Review

PSE has planned an upgrade of the distribution systems to incorporate automation for improved system visibility and control. These automation upgrades include the addition of equipment that allows for SCADA to both monitor system status and to provide for automatic or operator-initiated control. The installation of DMS to enable enhanced distribution automation is also being performed by many utilities.

Release of the EMS Version #1 system will take place in October 2012. This will be an enhanced system version, but it will not yet have the DMS installed. GE just purchased the company that will furnish the DMS portion, so it is not yet fully integrated into the Smallworld platform. This will be completed by mid-2013.

The SCADA system portion will be implemented first beginning in 2012. All call centers will have a read-only view of all known outages. The EMS system will have programs installed that will enable the system operators to perform a load analysis for the outage area.[59] The operators will then be able to decide on how to switch loads to restore as much of the system experiencing outage as possible without overloading any of the circuits. This will speed up the power restoration work. When this is coupled with remotely operating switches, the time for power restoration will be even shorter.

[59] System operator is the title used by PSE for distribution system operators. Load office is used for the PSE's transmission system segment.

The roll out of the system is scheduled to begin in July 2012, covering the Skagit area and then proceed clockwise until all of PSE's service territory is covered. A part of the system will be website links to outage maps for the affected cities[60]. There will also be automated updates of outages fed to the Customer information System (CIS).

These developments represent a significant investment by PSE in a modern DMS. Once the system is fully built, it should result in a significant improvement of PSE's abilities to handle major outages.

PSE has had an AMR system installed for many years. These are early versions of "smart meters," since they can and will report if a metering point has lost power. However, in the case of a major outage, the AMR system chokes because there are too many lost power reports flooding the system. Therefore, PSE still relies on customer calls for information about outages.

It is sufficient for PSE to know if a transformer has lost power, since that defines the outage area. This is known as soon as one customer has called in and reported an outage. Once distribution SCADA modules are installed along the distribution lines, this information will be immediately available to the system operators.

The new information platform will have an improved CIS to replace the CLX application. To perform this task, SAP's Customer Relations & Billing system will be installed. The new system will integrate all PSE-customer contacts, thus consolidating inquiries, billing, requests for service, and outage notification into one place. The system will eventually provide the latest outage information to the public via an online portal, enhancing customer awareness regarding the status of restoration from power outages.

2.4.6.8 Load Center Operation Review

PSE has a separate computer and communication system for management of its generators or power purchases and high voltage transmission system. This system has separate work stations for the following functions:

- Power dispatching
- Transmission system control
- Outage scheduling
- Load forecasting
- Contingency analysis.

The operator responsible for having sufficient power to serve all of the loads deals with the operation of the power plants under PSE's control, as well as obtaining the purchased power from other power producers.[61] A part of this system is a function that calculates a so-called

[60] These will only be useful if access to the Internet is available.

[61] At the time of the visit to the load center, the purchased power was up to 800 MW.

Area Control Error, which is used to balance the generation to match PSE's load on a minute by minute (or shorter time base) basis.[62]

The high voltage transmission system dispatcher monitors the state of the transmission lines, breakers, and transformers. If a line fault occurs such that the line is lost, it is the role of the dispatcher to manage any line overloads arising as a result of the failure and to restore the lost line back to service, if at all possible. The transmission line dispatcher also manages all requests for line outages or work clearances associated with the high voltage transmission system.

Outage scheduling requests require special studies for those segments of the system that must be de-energized to enable people to perform maintenance or other tasks. These studies take the expected loads, as well as other outages in place or requested, etc., into account to make sure that the outage can be handled safely, even if other unforeseen events were to occur during the outage. These are time-consuming tasks performed by specialists and are typically performed one or more days ahead of the time for the outage. There is a special workstation for such activities.

Load forecasting is also a special function. Historical loads, modified by the predicted weather for the studied time period (typically at least a day ahead), are used to forecast the future loads for each hour of the day. This becomes the basis for scheduling of both power generation and procurement to support the predicted load.

Contingency analysis is also performed in the load center. This function requires information about the system states in the generation and transmission systems operated by other utilities in the region, since abnormal system conditions in neighboring systems could impair the operating safety of PSE's system.[63] The contingency analysis process steps through the loss of any single component in the power system to determine if the system is still able to deliver power to all of the connected customers. Often, the process also includes the loss of any second component when one component is out of service. (This is the N-1-1 contingency where N is the number of connected elements.) In this case, the objective is to minimize the number of customers affected by the two outages. Since not all of the system states are known, the systems for this contingency analysis also utilize sophisticated statistical processing techniques to estimate the conditions of the unknown states.[64] This program is called a state estimator. It is a very important part of the contingency analysis because it can identify if the information about the system contains errors and where those errors most likely exist. A special workstation is often used for this analysis. Such a workstation is used in PSE's existing system.

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[62] If load and generation is not balanced, the electric clocks driven from the AC system will not keep accurate time, if the load is less than the generation, the power system frequency is above 60 Hz (cycles per second) and if the load is higher than the generation, the frequency is less than 60 Hz. BPA performs the function to keep the frequency constant and the time accurate from midnight to midnight.

[63] In 1994, an unknown scheduled line outage in BPA's system caused a collapse of the entire west coast power system when a new disturbance of the system arose.

[64] A state is a general way of referring to a mathematical element in an equation. For example, a line's connection status is a state element. (If the line is out of service, the state takes on a different value than if the line is connected.)

PSE is in the process of acquiring a new EMS system. Although the existing system is functionally quite adequate, the hardware needs to be upgraded. This new system will perform essentially the same functions as are being performed in the existing system, but with different hardware and new program packages. It will also be built to interface with the new communication systems being installed, or planned to be installed, in the near future by PSE.

2.4.6.9 Comparison between PSE and Other Utilities

Current utility trends are to increase the use of automation within their distribution systems. The automation includes both information technology systems as well as equipment to enable the visibility and control of their distribution systems. The systems include DMS, OMS, and customer management systems. These systems improve response to outages through the faster availability of data to identify location of faults, automatically switch power sources, and provide timely information to staff and customers.

From an outage management perspective, most utilities are moving away from manual systems to computerized systems that allow for more rapid update of information and communication with customers. Industry experience from major storms identifies the need for integration of the GIS, customer interface system, and OMS to manage and communicate information during outages. The integrated systems provide for more visibility on identifying outage extent and restoration, updating status, and communicating results. These computerized systems provide for multiple locations to share and view outage status.

The use of DMS is currently being included in utility plans. Current industry data indicate that approximately 20% of utilities have active DMS. However, because these systems are also required for enabling future applications of Smart Grid technologies (e.g., management of distributed generation on the system, effective use of Smart meter technology to allow for improved customer interface and improved system operations), many utilities are embarking on installation of DMS to increase system visibility and system control.

PSE is implementing an integrated OMS to improve outage reporting and status information. Many utilities provide outage status through their utility web-sites under the assumption that their customers have access to the web even during outage events, which might not be correct.[65] This functionality is based on the use of computerized systems that increase visibility into system status and that allows for on-line reporting by field staff. This information is updated in real-time and communicated quickly to customers.

2.4.7 Recommendations

Based on the work process assessment, additional recommendations include:

- Similar to previous recommendations, there are many programs underway at PSE to improve system reliability. It is recommended that the City meet with PSE on

[65] AM radio should be considered in addition to other communication means during major disturbances because most people would have access to AM broadcasts by means of a car radio.

an annual basis to understand what projects are being identified and scheduled each year with the specific goal of improved reliability. There are several programs underway to address prevention of outages and to reduce duration of outages. The City can monitor progress and the extent of those programs focused on improved reliability.

- PSE should continue with its implementation of current programs designed to improve overall system reliability in the City, including:
  - Upgrade of its information technology infrastructure, including implementation of the OMS and DMS.
  - Installation of distribution automation.
  - Consider a replacement program of distribution transformers based on estimated peak loads as a surrogate for operating temperature. This could reduce the number of transformer failures, oil spills, and also improve the reliability of the distribution system.
  - PSE is deploying a new OMS system over the next year that should provide improvement in overall outage communications. After deployment, it may be appropriate for selected City personnel involved in emergency response to understand the capabilities to assist in communicating to the Bellevue community.

2.5 Current System Assessment Recommendations

Recommendation Current 1: Reliability Progress

Finding: PSE has several programs underway to reduce the number and duration of outages, including:

- Hardening of the Downtown system
- Underground cable life extension and cable replacement
- Equipment replacement (older switches and transformers)
- Review of City circuit performance to address underperforming circuits
- Installation of reclosers
- Installation of SCADA
- Major information technology upgrade, including outage management and distribution management.

Recommendation Current 1: The City can and should proactively monitor progress and the extent of those programs focused on improved reliability of the City's power distribution system. This will require that the City add staff with power system expertise.

Recommendation Current 2: Reliability Progress

Finding: PSE has ongoing reliability initiatives and performs system-wide and targeted projects to improve system reliability.

Recommendation Current 2a: The City should track the reliability impacts experienced in the various neighborhoods. Since, in the future, PSE will be reporting additional reliability information including storm outages, the City can utilize this information to determine the effectiveness of the various reliability programs and projects, and to work with PSE in identifying circuits requiring attention. A fast track implementation of system improvements is an option for the City to explore with PSE, although accelerated investments might have a negative impact on the power rates.

The tracking of reliability performance is a trending metric that indicates how the system performs over time. Reliability can be tracked with and without storm information to determine how effective various projects and programs affect reliability. For example, if equipment changes are made, such as replacement of underground cable, then expectations are that equipment failures on these circuits should be reduced and the City can track this performance based on information provided in PSE's annual reliability reports to the City. The number of outages reported on these circuits would then be a measure to be used for the evaluation. If feeder ties are added or SCADA and other distribution automation solutions are put into place, then these projects or improvements should show an overall impact in total customer outage durations. Again, the City can assess these based on the information provided in PSE's annual reliability report to Bellevue. This type of assessment will provide the basis for the City to work with PSE on overall reliability improvement.

Recommendation Current 2b: It is recommended that the City meet with PSE on an annual basis to understand what projects are being identified and scheduled each year with the specific goal of improved reliability. There are several programs underway to address prevention of outages and to reduce duration of outages. The City can monitor progress and extent of these programs focused on improved reliability

Recommendation Current 3: Undergrounding Opportunities

Finding: Opportunities exist to advance undergrounding of lines by inter-utility cooperation.

Recommendation Current 3: The City should investigate opportunities for additional undergrounding of distribution lines through coordination of multiple-utility projects and evaluation of funding for conversion of overhead lines to underground cable circuits by forming local improvement districts. Further, the City needs to decide how to approach conversion of overhead distribution lines, used primarily in the residential areas, to underground systems, which requires special funding mechanisms.

Recommendation Current 4: Vegetation Management

Finding: The visual review of overhead circuits indicates that there are many substations and lines located in heavily wooded areas and the only way to significantly improve reliability is to perform more comprehensive tree trimming.

Recommendation Current 4: The City should review its vegetation policies specifically in the areas of substations to look at alternate vegetation approaches specifically where the risks for large scale disturbances related to vegetation issues is high.

Recommendation Current 5: Outage Management System

Finding: PSE is deploying a new OMS system over the next year which should provide improvement in overall outage communications.

Recommendation Current 5: After deployment, it may be appropriate for selected City personnel involved in emergency response to learn the capabilities to assist in communicating to the Bellevue community.

Recommendation Current 6: Recommendations for PSE

Finding: Several key components of high system reliability are within PSE's control.

Recommendation Current 6a: To achieve high reliability of the power supplied via the 115 kV power transmission lines, it is recommended that the system be reinforced to handle all N-1 contingencies by adding 115 KV transmission lines to the substations feeding the Downtown area.

Recommendation Current 6b: For the substations which at present are fed from a single 115 kV line, it is recommended that these substations be reinforced from a second 115 kV line to be able to ride through an N-1 contingency.

Recommendation Current 6c: PSE needs to continue to reinforce the distribution system to meet the N-1 criteria for the entire City.

Recommendation Current 6d: PSE should continue with its implementation of current programs designed to improve overall system reliability in the City, including:

- Continuation of system hardening projects.
- Installation and implementation of distribution automation.

- Upgrade of its information technology infrastructure, including implementation of the OMS and DMS.
- Consideration of a replacement program for distribution transformers based on estimated peak loads as a surrogate for operating temperature. This could reduce the number of transformer failures, oil spills, and also improve the reliability of the distribution system.

3 Future System Study

3.1 Study Scope

An assessment was performed to review the effects of growth on the PSE electric system within the Bellevue area. The assessment of the short-term capability of the system was addressed in the review performed in Section 2, which presented current PSE actions and plans to address reliability issues. This section addresses the future growth scenarios by looking at expected growth over the next 10 years plus the requirements for full build-out of the City. The study addresses the question "will the City have adequate and reliable power supply to meet future City growth needs?" Exponent's review covered the following:

- The City's Comprehensive Plan, which contains critical assumptions regarding load growth projections within the City
- PSE's long-term energy supply and transmission contracts
- Transmission line projects planned by PSE to enhance the capacity of the system that feeds the City
- Available power supply resources including PSE's own generation assets
- Demand-side assumptions including energy conservation and Smart Grid integration
- PSE's plan to incorporate a DMS and increased use of remote sectionalizing via SCADA
- Planned PSE reliability projects, such as the replacement and/or mitigation of underground feeder cables and equipment.

Based on this information, it is Exponent's opinion that the City should have an adequate and reliable power supply to meet the medium-term (5–10 years) and probably also to meet long-term (10–20 years and beyond) growth requirements.

3.2 Growth Scenario (Medium Term)

3.2.1 Study Approach

The medium-term growth scenario review was performed to assess the requirements for growth in each of the major systems affecting power delivery—generation, transmission, and distribution. The growth scenarios impacting the City are presented in this section along with a discussion of opportunities for use of Smart Grid technologies.

3.2.2 Generation

There are several questions that need to be answered when assessing the likelihood that the City will have an adequate electric power supply at competitive prices for the next 10 or 20 years. Some of the key questions are:

- Are the load forecasts for PSE reasonably accurate?
- Does PSE consider new demands or changes in the usage of electricity in its forecasts?
- Will PSE be able to acquire generation resources to serve all of its customers?
- What reinforcements will be made to PSE's 115 kV power transmission system that are needed to support the anticipated growth in the City?

PSE's planning process entails a comprehensive review of a multitude of factors that can impact PSE's ability to supply electric energy to its customers. All of this is documented in an IRP that is prepared on a biennial basis. This plan, which contains forecasts for PSE's electric as well as gas business, covers a 20-year time horizon.

The IRP document describes in detail all key issues with which PSE must deal. The IRP process covers, among others things, the macroeconomic climate, the political environment within which PSE operates, possible future new legislation of importance to PSE, past use of electricity, and potential savings that can be implemented cost effectively by PSE. Advanced statistical methods are used to develop various scenarios for the electric power and energy needs for PSE as an entity. The resulting forecast of the average annual electric energy needs is shown in
Figure 48. (The estimated number of megawatt hours can be obtained by multiplying the numbers in the graph by 8,760 hours per year.)

Chapter 3 of the 2011 IRP discusses the planning environment that PSE has considered. PSE states that in the near term, it recognizes that there are substantial uncertainties. PSE's planners recognize that the economy is foremost among the factors that can have a significant impact on the need for electricity in PSE's service area. Slow growth will benefit PSE and its customers because the likely result is a surplus of available electric energy. The effect of a continued slow growth is assumed to be a shift of the demand curve into the future before the economic growth will resume. Any change in the growth scenario will therefore be captured in the 2013 IRP, which is a reasonable approach. The IRP, however, does not provide specific information on growth in Bellevue. Therefore, this review covers all of PSE's service territory. Some aspects of the plan are discussed below.

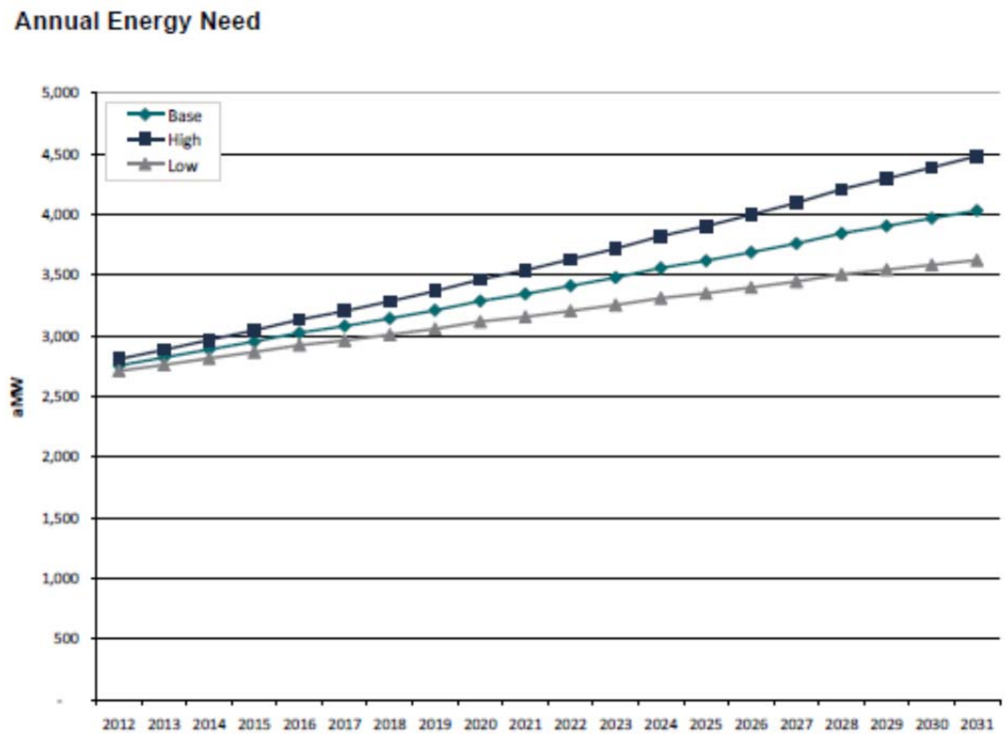

Figure 48. Annual Energy Need[66]

3.2.2.1 Demand Side Resource Assumptions

A significant portion of PSE's future peak power demand forecast is assumed to be reduced by encouraging its customers to install equipment and devices with reduced electric power consumption. Since the assumed reduction of the electric power demand is substantial, this aspect of the plan has been reviewed in some detail.

PSE is assuming that the electric power demand can be reduced by as much as an annual average of 645 MW in 20 years, as shown in Figure 49 (from the 2011 IRP), which summarizes the expected power reduction by business sector. It is expected that the residential and commercial sectors will each comprise approximately 50% of the demand reduction. The 645 MW value is estimated to equate to an 18% reduction of the retail sales by 2031 and a reduction of PSE's load growth by 50%.[67] It is assumed that 85% of this potential is achievable over time but the timing of the savings is uncertain. The plan for the near term assumes that energy conservation programs that cost up to $150 per MWh will be put in place. However, as will be shown below, while the saving in electric energy use might be realizable, some of the electric energy savings are likely to be offset by increases in consumption of natural gas.

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66 Reference 9, Chapter 5, Figure 5.2.

67 Reference 9, Appendix K, page 2.

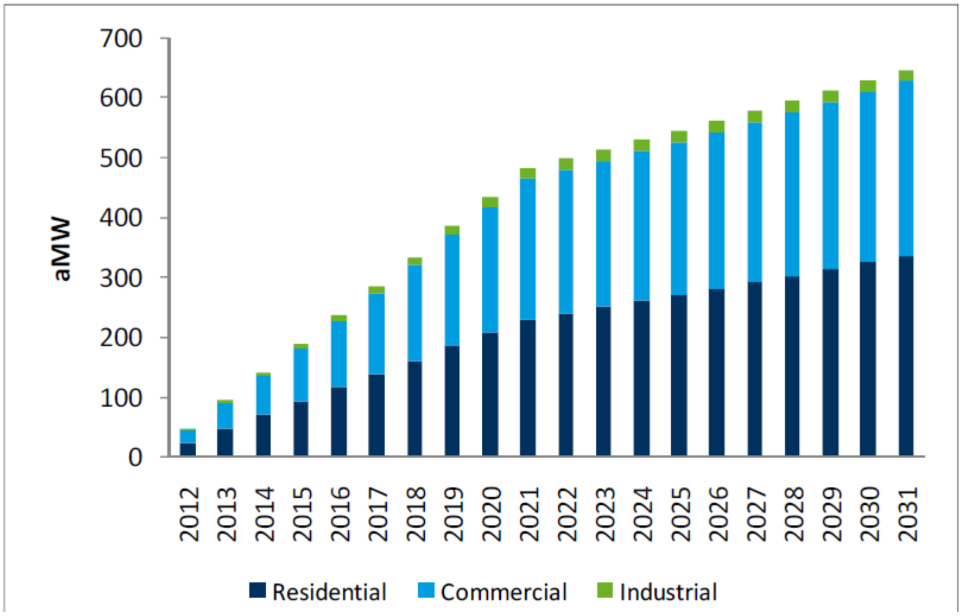

Figure 49. Electric Energy Efficiency Acquisition Schedule by Sector[68]

Figure 50 shows PSE's forecasted annual energy savings from use of more efficient lighting technologies within the time period from 2010 through 2031. An annual average energy savings of about 200 MW is estimated for year 2031.

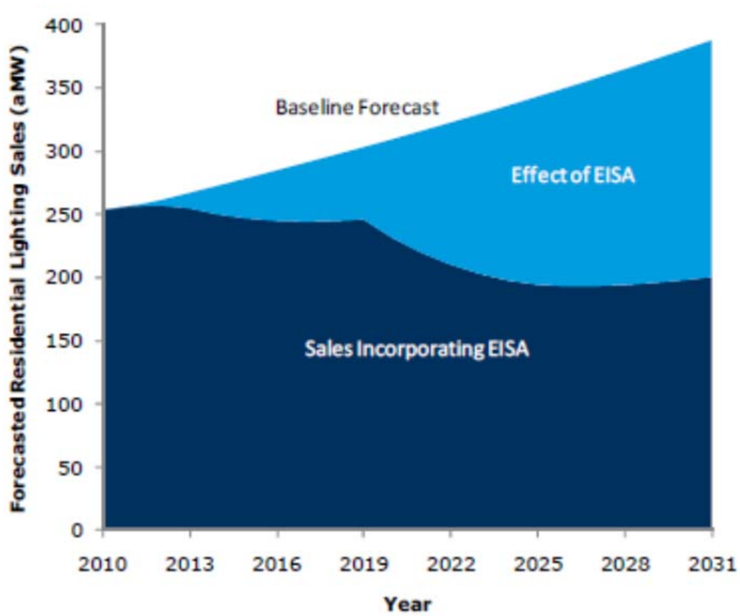

Figure 50. Residential Lighting Forecasts before and after Energy Independence and Security Act Adjustment[69]

68 Reference 9, Appendix K1, Figure 7

69 Reference 9, Appendix K1, Figure 3

Table 3 shows an analysis of the annual cost of owning different types of light bulbs and the energy consumed by each type. As can be seen in the table, most of the energy consumed by the incandescent light bulb is converted to heat. If heating is required for the space in which the energy is dissipated, then the energy from the light bulb is not wasted but useful for space heating. However, if the energy is dissipated in a space that requires air conditioning (cooling), then it will lead to even more energy consumed by the air conditioning unit so this is truly wasted energy.

Table 3. Comparison of Lighting Technologies[70]

	Incandescent Light	Compact Fluorescent Light	Light Emitting Diode
Power rating	60 watts	13–14 watts	12–13 watts
Lifespan/3 hours per day	333 days	7–9 years	22 years
Price per bulb	25–50 cents*	$1.99–$4.99	$30–$40
Annual energy use	66 kWh	14–15 kWh**	13–14 kWh**
Annual approximate heating contribution	62 kWh	4.4 kWh	4 kWh
Net light energy	4 kWh	9 kWh	10 kWh
Cost of Money @ 5%***	$0.03	$0.10–$0.25	$1.50–$2.00

Note: * - add 10% to the price of the light bulb to get the equivalent life time cost for 365 days.
** - assuming that 30% of the power generates heat.
*** - PSE's internal capital recovery rate is above 8%.

In the Pacific Northwest, air conditioning of residences is not likely to be used many hours a year during times when a light bulb is switched on so the cost of extra air conditioning can probably be ignored. Also, if the opportunity cost is counted by assigning a reasonable interest factor to the purchase price of the light bulb, it can be seen that the cost of owning a more efficient light bulb is so high that the consumer can almost afford to replace incandescent light bulbs every year and still nearly break even.[71] That is, there is no real incentive for consumers to buy more energy efficient light bulbs.

Note that this analysis does not take into account the cost of energy used to make the more efficient light bulb. However, it can be assumed that a significant portion of the price of the more energy efficient light bulbs represents the cost of energy used to produce it. Thus, when considering the societal savings in having more energy efficient lighting, the savings are probably exaggerated. Also, there is no guarantee that the newer light bulbs last as many years as is often stated.

70 Reference 14.

71 An interest rate of 5% is high at this time, but it is historically much lower than the average return on investments in the stock market.

The purpose of this simple analysis is to illustrate that the energy savings from using more energy efficient light bulbs will lead to more demand for natural gas, if natural gas is the energy source used for space heating, but it should reduce the peak demand for electric power used for lighting. Thus, it might reduce or postpone the need for construction of more electric power plants if the consumers are prevented from replacing the newer light bulbs with the old, cheap incandescent type bulbs. Similar reasoning would apply to other electric energy efficiency improvements where electric energy is merely replaced by thermal energy from other sources.[72]

3.2.2.2 Impact of New Technologies

The forecasting methodology used by PSE consists largely of extrapolations based on past load growth. However, the potential impact of electric vehicle usage has been analyzed and found to be low. The estimate is that about 50 MW will be added to the peak power demand by 2031 as a result of the increased use of plug-in electric vehicles.[73] Also, an increased use of distributed generation has been evaluated but found to not represent a significant portion of the electric mix in the near future. Technology breakthroughs could change this assumption.

An emerging technology is cloud computing, which has not been assessed. Because it is very early in the product mix that is available to consumers and businesses, it is difficult to forecast the potential impact of this offering. However, if it becomes widely accepted, it might lead to a significant expansion of computer server farms, which could put a high demand on the electric power system in locations where electric energy is inexpensive. At this time it is too early to predict if it is going to be successful and how it will be implemented. It is likely that this will have to be addressed in the 2013 IRP. Similarly, the impact of potentially new consumer electronics equipment, increased introduction of so-called smart appliances that can be controlled remotely, and other consumer electric and electronic equipment is not known and will therefore have to be left to future planners to assess.

3.2.2.3 Availability of Power Supply

Figure 51 shows the power that is available to PSE between 2012 and 2031. Also, on this chart is shown the forecasted peak power demand for PSE's entire service area. This graph shows the gap between the available power and the forecasted power needs. The peak power demand is assumed to be needed for 1 hour per day. The probability for reaching this peak load is assumed to be once over a 2-year period. The gap between the available generation and the estimated load has been adjusted as follows:

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[72] High efficiency equipment and products almost always cost more than the less efficient equipment would because more material and often higher cost materials are used to achieve the higher efficiency. High efficiency products often weigh more or incorporate more expensive lightweight materials such as aluminum or carbon fibers to obtain weight reductions. This requires more energy to make the products and equipment so a portion of the higher purchase price represents energy consumed prior to putting the equipment into use. The time for the payback in the form of energy savings to offset the increased energy to make the equipment can be long.

[73] Reference 9, Chapter 4, page 4-15.

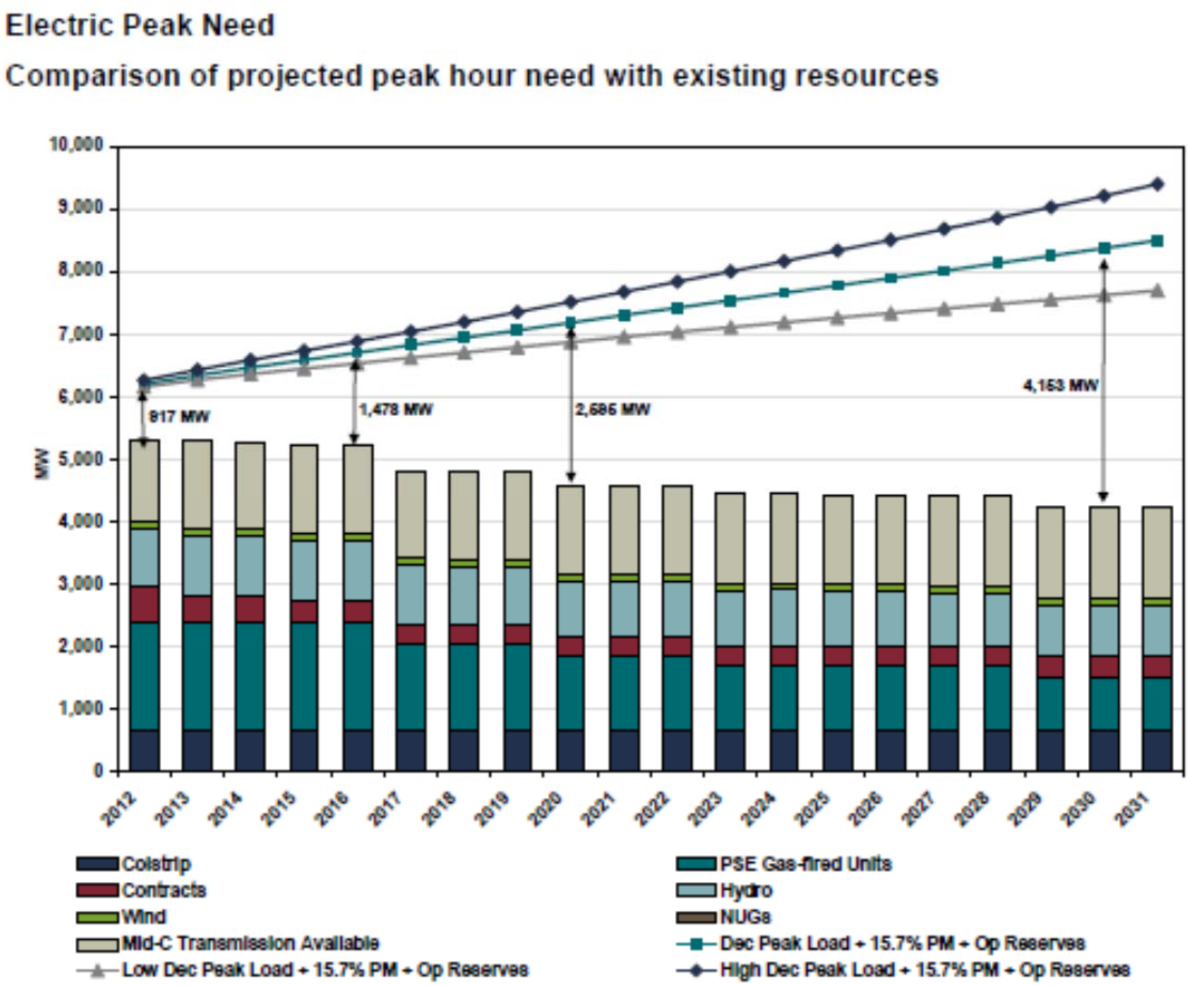

Figure 51. Electric Peak Need: Comparison of Project Peak Hour Need with Existing Resources[74]

- WECC requires a 15.7% margin between available generation and the forecasted peak power load. This is required to be in a position to survive a 5% loss of load probability.[75] In this graph the load forecast has been increased by 15.7% to account for the possible loss of generation instead of reducing the available generation by this amount.
- Since wind power is not a firm power source, the available wind power used in this forecast is only 7–8% of the wind power capacity.[76]

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74 Reference 9, Chapter 5, Figure 5.1

75 This means that PSE should be in a position to survive the loss of any single generator or any single bulk power transmission line without having to shed load.

76 Wind is poorly correlated with the peak power because a cold day, when a winter peaking utility such as PSE could be expected to see maximum power demands, might be associated with stagnant air (no wind). That is, wind generation is an energy source but not a firm power source that is available at any time.

- Under the rules of the Northwest Power Pool, PSE must also reserve 5% of hydro and 7% of thermal generation as a contingency reserve. This generation must be available within 10 minutes, and 50% of it must be spinning so that it will be able to pick up loads almost instantaneously. This is also included in the graph as a margin between the available generation and the forecasted load.

These operating margins are required for the region's electric utilities to provide electric power reliably to the people in the areas served by the interconnected utilities in the region. In addition, PSE is required under Washington statutes RCW 18.285 to have the following renewable energy credits: 3% of supply-side resources in place by 2012, 9% in 2016, and 15% in the year 2020.

For comparison, Figure 52 illustrates the peak-hour load forecast for Bellevue for 2010–2030. The forecast is based on the PSE-provided estimate of 475 MW for the year 2010 and the annual peak-hour load-growth values shown in Figure 51 for PSE's total service area.

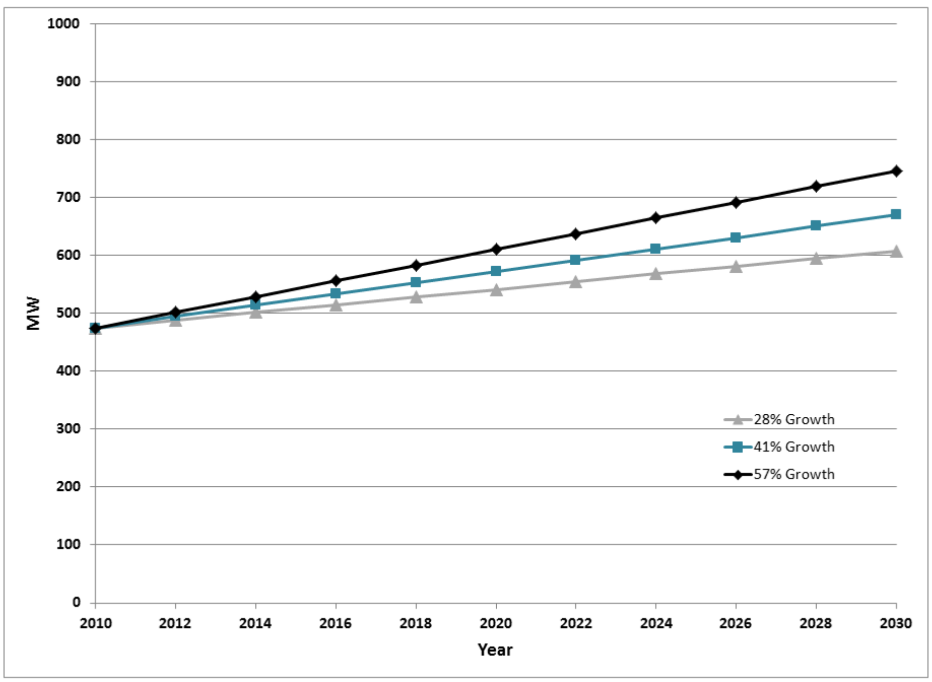

Figure 52. Projected Peak Power Needs for All Substations Feeding Bellevue, Using the Same Growth Rates as Shown in Figure 51.

3.2.2.4 Retirement of Power Supply Agreements

3.2.2.4.1 Resource Plan for the Time Period 2012 through 2020

The lead time for new electric utility facilities could be 10 to 12 years for lines, but the lead time might be only about half that for new, modular combustion turbine plants. When dealing with such long lead times, the utilities have to make decisions for investments in new facilities long before they know for sure that the facilities will be required. Therefore, the planning horizon covering the next 10 years has to be as accurate as possible. In particular, the longest lead time investments have to be planned out in detail and work has to be initiated to enable the investments to be made and the facilities built to meet the needs of the utility's customers. This entails significant risks.

PSE's power capacity needs are shown in Figure 51. This figure shows a decreasing trend for availability of power sources. The following significant reductions in PSE's availability of generation resources over the next 7 years are noted in the planning document:[77]

- A reduction of 387 MW at the end of 2011
- A reduction of 150 MW in February 2012
- A reduction of 125 MW in March 2013
- A reduction of 75 MW in February 2015
- A reduction of 333 MW in February 2015
- A reduction of 298 MW in December 2016
- A reduction of 75 MW in June 2017
- A reduction of 251 MW in March 2018.

Other changes beyond 2018 are also listed in PSE's IRP. By 2020, PSE will have lost a total of about 1,050 MW. As shown in Figure 51, PSE estimates that the generation gap in the year 2020 is going to be 2,686 MW.

3.2.2.4.2 New Power Sources

A review of the PSE IRP was performed to determine PSE's needs for new power sources to meet the current IRP mid-range forecasts. The results of this review are discussed below.

PSE needs to acquire new power sources to make up for the expired power purchase agreements. There are two kinds of sources needed to operate an electric utility reliably. One source is needed to supply power for a few hours during the morning and evening peak power

[77] Reference 9, IRP Chapter 5.

loads.[78] The other is to supply power to the base loads 24 hours a day, 7 days a week. The power sources needed to supply electric power during the peak load periods should be inexpensive to build since they will only be used for short periods of time each day, but need to be able to sustain frequent starts and stops. In this situation, the cost of the fuel is less significant. (If the capital cost for building the peaking units is high, the fuel cost must be very low, which is the situation for pumped storage systems.) The plants used for base load are not required to start and stop frequently, but must operate reliably, efficiently, and continuously. PSE can and must cover the emerging power supply gap for power peaks as well as for base loads. It can achieve this by either 1) building and owning power plants, 2) completing power purchase agreements under long-term contracts, or 3) buying power on the open spot market. According to the IRP, PSE will most likely use all three of these options. The spot market option is the riskiest if a power supply shortage should arise in the region, but until such time, it might provide opportunities for relatively low cost power purchases.

Wind and solar power plants do not fit this mix since they are not reliable power sources available on 24 hours per day, 7 days per week basis. These are energy sources that have to be complemented by conventional power sources that can cycle rapidly up or down to match the variations in available wind and solar power. Therefore, PSE has almost no alternative but to use natural gas for any new generating plants it needs to build, in order to have guaranteed capacity available for its customers.[79]

PSE assumes that the time required to obtain permits for and to build a new gas turbine plant is 4−5 years. Because there is a surplus of power in the Northwest at this time, PSE is not planning to build any new fossil fuel-based power plants, but is using a Request for Proposal to acquire power on the open market. As there is a power surplus in the region, it should be possible for PSE to acquire enough power to cover the gap between the forecasted demand and the availability of generating plants owned or controlled by PSE. However, for the longer term, PSE will probably have to build new power plants. Future prices for power generation can be significantly affected by possible future costs associated with CO_2 generation, which also might force a shutdown of the 716 MW Colstrip power plant portion that is owned by PSE. If significant power rate increases should occur in the future because the spot market dries up or new regulations force shut-down of fossil fuel-based power plants (or increases the cost of power from fossil fuel-based plants), this could affect the growth of the City.

3.2.3 Transmission

Chapter 7 of the 2011 IRP discusses the needs for reinforcement of PSE's electric transmission system during the next 10 years: 2011 through 2021. No part of the plan addresses needs for a 20-year planning horizon, which is probably appropriate because the uncertainties over such a long time horizon are substantial. Also, it should be possible to complete transmission line

[78] PSE has two daily peaks according to information provided by PSE's planners. One is associated with the morning waking up time period and the other arises during dinner times in the late afternoon and early evening.

[79] New hydropower plants are not likely to be built in the Northwest and coal power plants will probably not be an option for the future either. Therefore, the only readily available fuel is natural gas.

projects as needed over a 10-year time period. Therefore, a 10-year rolling planning horizon should be adequate.

PSE anticipates that 200 miles of new transmission lines operating at voltages above 100 kV and upgrading of 300 miles of existing transmission lines will be needed. One of the major uncertainties in the plan is the potential impact of new regulations. For example, new regulations were issued in 2007 through the Energy Policy Act of 2005 regarding electric system reliability, which required PSE to make investments in software and hardware for operation of its 100 kV and above power delivery system.[80] Other uncertainties relate to the use of emerging distributed generation technologies, which might become an acceptable alternative to the use of central electric power stations. If distributed generation becomes cost effective, then the need for long distance power transmission lines will be reduced. Thus, for long-term planning, constant scanning of the environmental and technical factors that can impact the need for power lines is required.

BPA handles about 70% of all of the bulk power transmission in the Pacific Northwest.[81] The transmission system in the Northwest is illustrated in Figure 53. The figure shows PSE's power plant facilities located in eastern and western Washington State. The construction of wind power plants in Eastern Washington and in Idaho (a few but not all of which are shown in the figure) has caused increased demands on the transmission lines leading towards western Washington and Oregon. These lines also carry power from the coal-fired power plants in Wyoming and the hydropower from dams in the basins of the Columbia and Snake Rivers. The corridor along Interstate 5 is also heavily loaded because it is the interface between British Columbia and the lines down along the Pacific Coast toward California. PSE states in the IRP that the region often suffers from transmission system constraints resulting in curtailment of firm contractual transmission rights. This is also discussed in a white paper published by BPA in 2006.[82] The Columbia River treaty also adds to the congestion of the transmission lines in and around Puget Sound.[83] According to the agreement, Canada is entitled, at least until the year 2024, to receive power from the United States as compensation for its cooperation in the construction and operation of the dams along the upper Columbia River basin. At present, the annual entitlement is estimated to be about 550 MW with a peak of about 1,440 MW. This power will flow across the bulk power transmission lines through the Puget Sound and Cascade Mountain corridors. This is difficult to achieve during the winter season since the electric power demands in the region are heaviest during the colder fall and winter months.

80 Reference 9, Chapter 7, page 7-19.

81 Reference 9, IRP Appendix E, page E-2.

82 Reference 15.

83 Reference 16.

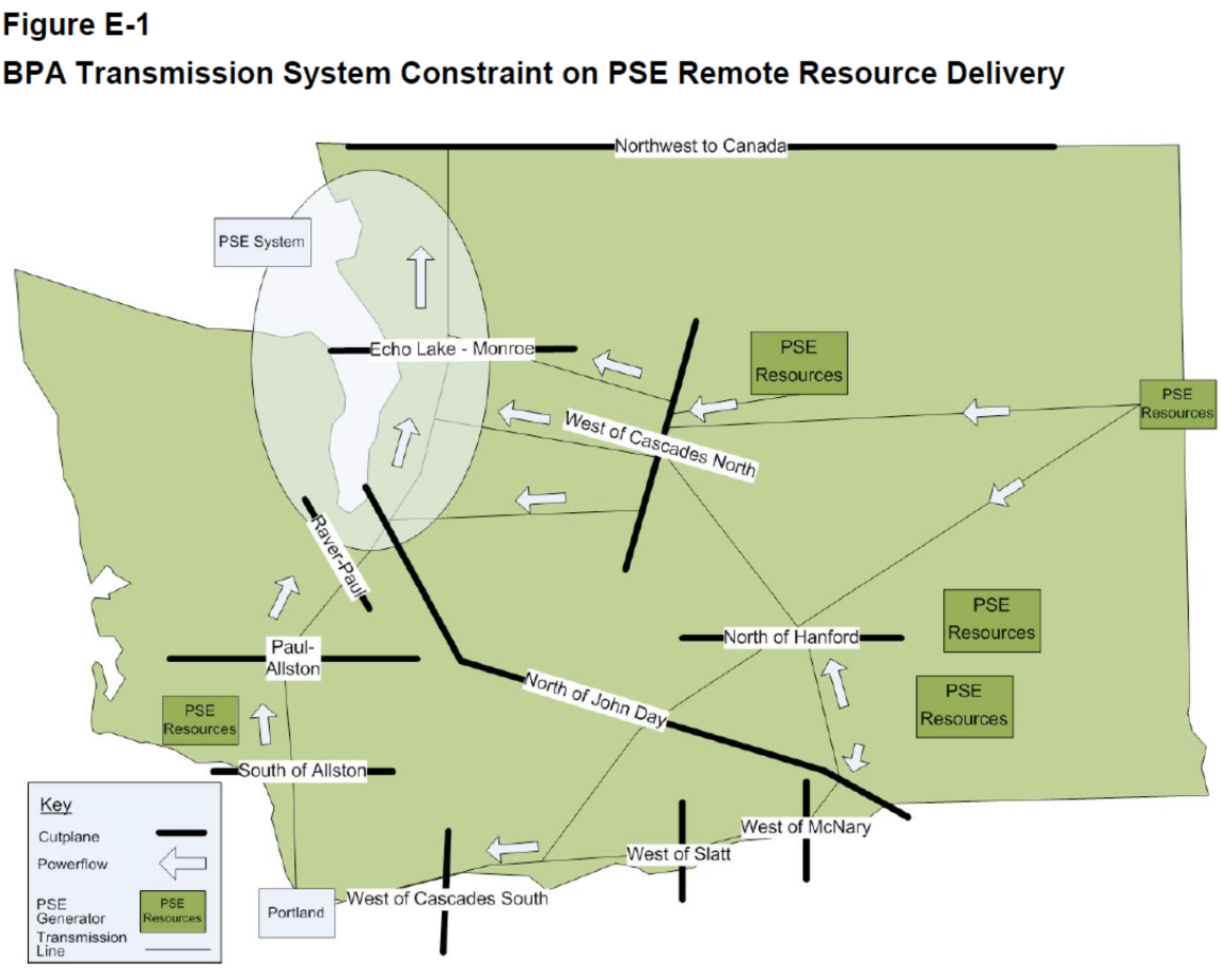

Figure 53. BPA Transmission System Constraint on PSE Remote Resource Delivery[84]

PSE anticipates a need for expanding transmission capacity towards the Mid-Columbia basin. It has rights at present to about 2,300 MW of capacity which is necessary to meet peak load requirements. That is, there is at present sufficient capacity through the Cascades but it is vulnerable to interruptions during severe weather. It would be difficult for PSE to build its own bulk power transmission lines. Therefore, the most likely route will be to work through BPA's network open seasons (NOS) process, which will probably be pursued by PSE through its membership in the Columbia Grid organization. BPA approved the latest NOS in 2008 and is at present pursuing projects to enable power from PSE's Lower Snake River wind power project. BPA is also strengthening the Interstate 5 corridor and the lines west from the McNary Dam, all of which should directly or indirectly help PSE and other utilities operating in the Puget Sound area. However, more is going to be needed.

In its IRP, PSE discusses the demands put on the bulk power transmission systems in the region by the anticipated 5,000 MW of wind power that will be needed to meet the demands from the

[84] Reference 9, Appendix E, Figure E-1

regulators for renewable generation in the states of Washington and Oregon. Wind power is challenging for transmission system operators because such power can fluctuate significantly from the scheduled power flows over short time periods. This can lead to voltage instability as well as thermal overloads if no facilities are available to mitigate the fluctuations.

The IRP is as detailed as possible considering the uncertainties surrounding all forecasts relative to the needs for future additions to the bulk power transmission systems in the Northwest. The plan appears to be sound for the next 10 years. Beyond the 10-year horizon, the uncertainties are too numerous to make any plan or forecast credible.[85]

In regards to growth in Bellevue on the 115 kV system supplying power to the City, there are significant reinforcements required to accommodate growth. Growth in the City's Downtown and the Bel-Red corridor requires reinforcement of PSE 115 kV substations and lines feeding the City. The following reinforcements of the 115 kV systems feeding the City are anticipated:

- The Ardmore substation in the City of Redmond is scheduled for completion in 2012. Two spans for a line still need approval from the City to complete this project. Once the Ardmore substation is finished and the two spans built, the Interlaken substation will be decommissioned.
- The Spring District might have four new office towers, which at build out will probably require between 30 MW to 40 MW. PSE currently plans to serve the early loads from a new 25 MVA bank at the Northrup Substation. It is anticipated that a new substation will be needed prior to full build-out of the Spring District and at other sites in the Bel-Red Corridor. This substation is labeled Vernell on PSE's comprehensive plan map.
- Clyde Hill needs to be expanded between 2016 and 2020 to meet anticipated load growth in Downtown, which will require about 50 MW and at least two more transformer banks to feed more power through the west loop corridor. The line through Clyde Hill carries about 130 MW, which is a heavy load for a 115 kV circuit.[86]

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[85] If there is any omission in the plan it would be that it does not discuss how new technologies can be used to utilize the existing transmission lines better because 500 kV lines are typically limited by their electrical characteristics but able to handle higher loads without exceeding their thermal load limits. New technologies, often referred to as FACTS technologies, are available that should enable the loads carried by the lines to be increased at the expense of increased line losses. (FACTS stands for Flexible AC Transmission Systems developed by EPRI in cooperation with U.S. electric utilities, GE, and Westinghouse in the early 1990s. For more details see Hingorani, N.G., and L. Gyugyi. 1999. *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems.* Wiley-IEEE Press. Available at: ISBN 978-0-7803-3455-7). However, if the loads are only required for relatively short periods per day or seasonally, systems to increase the electric loading of lines could be installed with a 1.5–2 year lead time. However, unknown contractual or technical barriers might exist, which make these types of installations difficult to accept by stakeholders with an interest in the transmission systems.

[86] A 115 kV circuit using Tern conductors has a maximum rating of 239 MW in the winter so the Clyde Hill circuit is loaded to 54% of maximum winter rating.

- The Lakemont area is at present served via distribution circuits from Somerset, Eastgate, Hazelwood, and Goodes Corner (see Figure 32) Any additional growth in the Lakemont area could not be served from the Eastgate substation because there is no room at this substation for the third transformer bank that would be needed to serve the increased load. There are also indications of business expansions in the Eastgate commercial area, which will have to be considered by the planners. Although tapping the transmission line at Somerset to serve a new Lakemont substation seems like an option, this would, in fact, put too much load on that line.

The permitting process for these needed 115 kV system reinforcements in the City is expected to be lengthy given the size of these projects. Collaboration and cooperation between the City and the City of Redmond is needed to deal with the Bel-Red corridor. Strengthening of the power system feeding the Downtown requires cooperation between PSE, the City, and the business community in the Downtown. Also, projects to handle any increased growth in the Lakewood area, for example, will be significant since the growth would probably require a new substation.

3.2.4 Distribution

PSE uses a mixture of short-term and long-term planning to address load growth and reliability issues. Load growth planning includes submission of project proposals to add extra distribution substation capacity including transformers and related switchgear and additional distribution circuits. Reliability planning includes project proposals that generally decrease outage time and/or frequency by providing alternate transmission feeds to distribution substations, by increasing switching capability through additional distribution feeds and switches, by increasing the use of SCADA for remote data gathering and switching, and by proactively replacing troublesome equipment, including replacement of bare overhead conductor with covered overhead conductor.

Load growth within the City has been somewhat stagnant for the past couple of years, and load growth planning for the City is challenging due to a heavy dependence on economic conditions. The Downtown circuits are fed from the Lochleven, Clyde Hill, North Bellevue, and Center substations, (Figure 33) for which the Downtown represents approximately 80% of the load.[87] Figure 54 illustrates the situation for both summer and winter peak loads, and shows that the peak winter load for the substations (including both Downtown and non- Downtown load) is approximately 130 MW. To meet the demand and leave sufficient supply margin for contingency situations, PSE has capacity expansion projects planned that will add 100 MW to the Downtown. Additionally, approximately 30–40 MW of load growth is predicted in the Bel-Red corridor, including the Bel-Red Overland Transportation System (BROTS) light rail system, and growth within both Bellevue and Redmond is expected to impact the distribution systems within both cities.

[87] The 80% figure is calculated from the peak winter and summer load data shown in Figure 54. The data were provided by PSE system planning personnel.

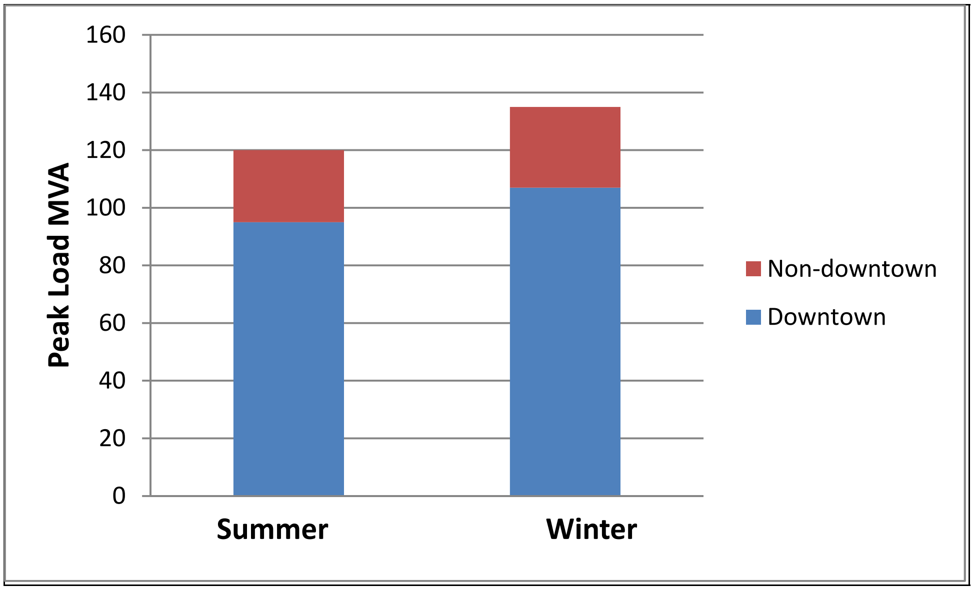

Figure 54. Peak load data for the substations feeding the Downtown, including non-Downtown load (2009 data). The substations are Clyde Hill, Lochleven, North Bellevue, and Center.[87]

The Bellevue outage trends (for both number of outages and customer minutes) generally show a decrease in the period from 2006–2010, no doubt in large part due to PSE's replacement of portions of its older installation, especially underground cables. Planned projects for the near term include a continuation of this process, along with replacement of many trouble-prone distribution switches used to sectionalize the system during outages and to provide alternate feeds. PSE also continues to address overhead line–tree contact by installing covered conductors in many locations, and animal guards where warranted.

PSE has made a commitment toward improving the operation of the distribution system in high density load areas such as the Downtown through its adoption of a structured SCADA modernization plan. An integral part of the plan is the upgrade of distribution switches over several years in the Downtown to allow remote switching via SCADA control. Remote switching is an important part of improved response to outages on the distribution system by allowing increased flexibility in terms of system configuration changes to restore power more quickly to as many customers as possible. Presently there are approximately 100 underground and pad-mounted aboveground switches that serve the Downtown and are candidates for the upgrade. PSE's strategy will be to focus on switches that:

- Are part of the Downtown reliability ring
- Are the first load switches of each circuit
- Serve difficult-to-access circuits, large loads, or that have a significant impact on restoration times
- Serve critical locations.

This investment in infrastructure is scheduled to take place over the next several years. Additionally, pilot testing of an automatic power restoration system is planned for 2012 utilizing some of the distribution switches within the Downtown reliability ring. If this program proves successful, PSE plans to extend its use in the following years. This system should further reduce the time needed to restore power to as many customers as possible as a result of the use of automated switching logic and control of alternate feeds.

The increased use of remote manual control also necessitates upgrading the SCADA system itself. Further discussion of these systems was presented in Section 2.

3.2.5 Smart Grid Technology

3.2.5.1 Background

Title XIII of the Congressional Energy Independence and Security Act (EISA) of 2007 describes the Smart Grid as follows[88]:

> "Section 1301 establishes a federal policy to modernize the electric utility transmission and distribution system to maintain reliability and infrastructure protection. The term "Smart Grid" refers to a distribution system that allows for flow of information from a customer's meter in two directions: both inside the house to thermostats, appliances, and other devices, and from the house back to the utility. Smart Grid is defined to include a variety of operational and energy measures—including smart meters, smart appliances, renewable energy resources, and energy efficiency resources."

Specifically, the following activities are covered by this legislative act:

- Section 1302 calls for the U.S. Department of Energy (DOE) to report to Congress on the deployment of Smart Grid technologies and any barriers to deployment.
- Section 1303 directs DOE to establish a Smart Grid Advisory Committee and a Smart Grid Task Force to assist with implementation.
- Section 1304 directs DOE to conduct Smart Grid research and development (R&D) and to develop measurement strategies to assess energy savings and other aspects of implementation.
- Section 1305 directs the National Institute of Standards and Technology (NIST) to establish protocols and standards to increase the flexibility of use for Smart Grid equipment and systems.
- Section 1306 directs DOE to create a program that reimburses 20% of qualifying Smart Grid investments.

88 Reference 17.

- Section 1307 directs states to encourage utilities to employ Smart Grid technology and allows utilities to recover Smart Grid investments through rates.
- Section 1308 requires DOE to prepare a report to Congress on the effect of private wire laws on the development of combined heat and power facilities.
- Section 1309 directs DOE to report to Congress on the potential impacts of Smart Grid deployment on the security of electricity infrastructure and operating capability.

As loosely defined in the Federal Statue, the Smart Grid encompasses development of new standards under the auspices of NIST instead of using the normal voluntary, consensus standards development paths such as IEEE and American National Standards Institute. Furthermore, the legislation includes subsidies for certain R&D projects and it also encourages but does not mandate that states use Smart Grid technologies. Later amendments to EISA also include provisions to support development of alternative energy systems and technologies.

WUTC was enabled to have WUTC staff undergo in-depth training on Smart Grid technologies and applications under an American Recovery and Reinvestment Act grant. It led to a utility Smart Grid reporting rule, a review of utility Smart Grid investment reports, status updates, and pilot Smart Grid and demand-response programs.[89] In order to encourage investor owned utilities (IOUs) in the state of Washington to consider the value of a Smart Grid, the WUTC adopted a rule that requires such utilities to file an biannual Smart Grid Technology Report on Smart Grid technologies they are considering.[90] In regards to electric vehicles, WUTC initiated a work session to consider its role in the development of an electric vehicle infrastructure and other regulatory issues relating to electric vehicles in Washington. This session addressed issues such as whether the resale of electricity at public charging stations ought to be subject to economic regulation, the extent to which existing laws provide protection to consumers who purchase electricity for vehicle recharging, and whether WUTC will need to address additional ratemaking considerations for IOUs (such as time-of-use tariffs).[91] WUTC conducted a foundational study funded by the National Association of Regulatory Commissioners to better understand dynamic pricing and its applicability to Washington regulated electric utilities.

Another example of a regulatory response to EISA is SB17, enacted by the California legislature in 2009, which defines Smart Grids further. This bill recognizes that national or international standards might lead to more cost effective solutions than standards that have limited support from the business community. The bill also establishes that the California Public Utilities Commission (CPUC) has the authority to decide on rate recovery of investments related to Smart Grids, which is also the prerogative of WUTC for the state of Washington. Prior to the EISA in 2004, CPUC directed the three largest California IOUs to submit advanced metering infrastructure (AMI) business cases along with full deployment proposals for the purpose of advancing CPUC's policy to expand demand response in the state. The deployment of smart

[89] Reference 18.

[90] Reference 19.

[91] Reference 20.

meters is expected to be complete by 2012 in California. PSE has had automated meter reading, which is one of the functions of a smart meter, capability for a long time. Over the past 5 years, CPUC has also initiated Demand Response proceedings in California, which is also covered in WUTC's study. As a result, the IOUs in California operate various demand response programs and dynamic pricing tariffs that are designed to provide incentives to customers to reduce their electricity usage during peak hours. Distributed generation is also a part of CPUC's regulatory mix, which covers distributed generation on both the customer and utility wholesale sides of the electric meter. WUTC is embarking on regulations similar to what other states are doing in response to the EISA.

Recently the security of the communications systems used by the utilities has become a major issue.[92] In the past, the electric utilities relied primarily on their own communications systems for control of their power plants, lines, and substation equipment This made the electric utilities relatively immune from hackers since access to the communication ports was primarily from secure sites under the utilities' control. Because of the transition to more use of public communications systems, multiple issues has arisen on how to keep communications systems for Smart Grids or meters secure. There is a legitimate need for consumers to be able to interrogate the meters to find information about their energy use and to control when and how they use electric energy. Thus, there has to be a public access portal to the system. Because communications tools are changing very rapidly (e.g., wireless and mobile technologies), it can be difficult and costly to maintain users' access to their meters. Public access also enables hackers to break into the systems used for such access and control. There is also an overriding need for the electric utilities to be able to control switchable loads through the smart meters to shave power peaks as a part of the demand response programs. For outage management, the utility's ability to communicate with the meters must not be affected by a communications system overload, which could arise during major emergencies such as during the 2006 storm that caused widespread outages in the Puget Sound area. These issues have national security implications, which are recognized at the federal government level, as well as cost implications for the utilities, which are under the purview of state regulatory agencies. At this time, there is no recognized standard for how to address these issues, which leaves each state and possibly each utility to find their own solutions.

Distributed generation is a part of the Smart Grid mix. Utilities are already well versed in how to safely allow their customers to connect solar systems to the grid. Also, a large number of backup generators are installed to supply power in case of a power outage. The smart meters will enable establishment of more flexible rate schedules, which may include real time pricing structures for the power exchange. Thus, distributed generation does not add any complexity, except that distributed power generation from sources such as solar cells, which are not dispatchable, cannot be included in any demand response function.

Pacific Gas & Electric Company (PG&E) prepared a Smart Grid Deployment Plan for CPUC in June 2011.[93] In this plan, PG&E outlines its vision as follows: "…to provide customers safe, reliable, secure, cost-effective, sustainable and flexible energy services through the integration

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[92] Reference 21.

[93] Reference 22.

of advanced communications and control technologies to transform the operations of our electric network, from generation to the customer's premise." In addition to the regulatory requirements, the strategic objectives driving PG&E's Smart Grid initiative are briefly described as follows:

- Smart meters intended to stimulate customers to use energy more judiciously to achieve cost savings, and third parties to create energy solutions and tools for customers to use.
- Use of demand management to obtain operational efficiency primarily by reducing the demand for power during peak power periods and to tap into the ancillary service markets for efficient use of such resources. Environmental impact related to supply-side energy resources is also an objective.
- Investments to support the emerging market for electric vehicles. This anticipates investment in the T&D systems, plus (possibly) monitoring and metering systems to supply power to electric vehicles.
- Improved forecasting techniques to better match demand and supply of electric energy. This need is stated in anticipation of increased use of renewable energy sources to meet statutory requirements.
- Integration of large-scale renewable energy resources is expected to require investments in new technologies in order to maintain the reliability of the power system in view of the high variability of the power generated by the emerging renewable power sources.
- Enhanced grid outage detection, isolation, and restoration is also a part of the strategy, with anticipated investments into advanced communications technologies and control systems to assist utility operators and repair personnel to locate damaged equipment or outage areas, isolate the problem, and quickly restore power, which will minimize the customer outage times.
- Utilization of advanced monitoring and control technologies for improved equipment condition assessment and possibly incipient fault detection to prevent system problems that might lead to system disruptions.
- Improved system's voltage control to minimize system losses by using advanced technologies, including the use of sensing, telecommunications, and control systems to reduce power losses in the utility delivery system and in customer equipment.
- Continuously monitor technology developments to take advantage of new Smart Grid technologies. This strategic objective includes subjects such as those related to cyber security, new technology testing, standards development, etc., as necessary in order to achieve PG&E's other Smart Grid strategic objectives.

For the most part, these are the objectives that the utility industry has been pursuing for decades. Many of the enumerated objectives drove the R&D programs established by the Electric Power Research Institute (EPRI) beginning in 1973. Some of EPRI's R&D developments resulted in:

- Digital microprocessor-based protective relays used for detection and clearing of electric system equipment faults for both T&D system applications (mid-1980s). As a part of this effort, the use of so called phasor measurement units for improved stability monitoring and control of power systems were demonstrated in the early 1990s.
- New power electronic-based equipment for management of power flows and for voltage control of transmission systems (late 1970s through mid-1990s).
- Equipment and computer tools for thermal loading of transmission lines under emergency conditions (early 1990s).
- Automatic meter reading technologies.
- On-line and off-line tools and methods for management of transformer loading and incipient fault detection in transformers, breakers, and other substation equipment (1980s).
- The development of a unified communication protocol for utilities was initiated in 1986 by EPRI.

Obviously, these technologies have evolved and been improved upon over the years. However, out of the stated objectives, only the following are relatively new issues requiring innovation and new technologies:

- The need for utilities to manage demand by switching customer loads and the possibility for real time pricing of power has led to the need for smart meters with an associated communication system infrastructure.
- The need for forecasting and power system management tools that can operate on a second-to-second or minute-to-minute basis emerged as a result of renewable power systems such as those provided by wind turbines.
- Demand side management tools and systems that can be used for peak power shaving to avoid starting up costly and potentially polluting power plants. The driving force behind this is primarily emerging regulations. These tools will probably also utilize the smart meters to shed loads. It should be noted that these techniques probably have little impact on energy use since the shedding of loads will basically move the energy consumption to time periods after the peak load periods.
- The increased use of public communication networks for power system management, power scheduling, and for interfacing with independent system operators or similar organizations has resulted in cyber security issues, which

were essentially non-existent when the utilities relied almost exclusively on their own communication networks.

- Customer and regulatory demands for improved power system reliability is leading to increased use of remotely operated sectionalizing switches in the power distribution systems. Such systems have been available for over 30 years, so no new technology needs to be developed to achieve these kinds of improvements. However, lower communications system costs are making distribution system automation less costly, although higher reliability often can be better achieved by more frequent tree trimming.

The Smart Grid strategies promulgated by the regulators have not dramatically changed the need for technology, but do enable the utilities to invest in the existing technologies and to get the investments put into the rate bases so they can be recovered by adding the costs to the power users.

3.2.5.2 Electric Vehicles

Electric vehicles represent an emerging and largely unknown load for the utilities. The market acceptance of electric vehicles is uncertain and the demand on the power systems for energy to recharge the batteries in electric vehicles is difficult to foresee. Some of the newer electric vehicles are basically hybrids with larger batteries that enable driving longer distances by having an onboard engine powered by fossil fuels to provide propulsion for the vehicles when the battery is depleted. These are the so called plug-in hybrids. These vehicles might have a range on the electric drive of 15 to 40 miles whereas the vehicles without an onboard fossil fuel-powered engine might have a range of 100 miles or more. The latter type could work as a commute vehicle that might not require charging stations to be available at the place of work unless they are used in cold climates where there will be a need for battery keep-warm type systems during work hours. Using a vehicle with an advertised range of 35 miles at an equivalent fuel use equal to about 90 miles per gallon leads to the following:

- Battery capacity: about 16 kWh[94]
- Charging time @120V: 10 hours
- Estimated charging power assuming 90% battery depletion and 90% charging efficiency: 1.6 kW
- Charging time at 240 V: 4 hours
- Estimated charging power assuming 90% battery depletion and 90% charging efficiency: 4 kW.

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[94] The energy stored is approximately equal to 1/3 gallon of gasoline if it is generated by a power source that is 100% efficient or about 1 gallon of gasoline if the source is a thermal power plant. In the latter case, the actual energy efficiency is about 35 miles per gallon.

If there are 1,000 vehicles needing recharge each morning after the commute to work, the aggregate load will be about 4 MW over 4 hours or 16 MWh if the recharge time is 4 hours. If a plug-in hybrid is charged between 8 a.m. and noon, the charging might be completed before the peak loads typically occurring after noon.[95] If the vehicles are placed back in the garages after work, the recharging should be delayed to avoid adding to the peak loads related to tasks (such as preparing dinner) associated with the time after working hours. Larger electric vehicles can be expected to require more energy to recharge but smaller-sized true electric vehicles might not need to be recharged during working hours. However, all electric vehicles relying on lithium or similar energy storage technologies will require power to keep the batteries above freezing. Onboard heaters are used for this function. This might add 1–1.5 kW to the power demand but the duty cycle for this depends on how cold the temperature is where the cars are parked. However, this can extend the power demand cycle beyond the charging times estimated above. These needs must be considered in planning to meet the demands of the new plug-in hybrid vehicles and electric vehicles.

3.2.5.3 Smart Grid Benefits

Various estimates of Smart Grid benefits have been published. EPRI has published reports that include cost-benefit calculations.[96] PG&E's Smart Grid document contains estimated benefits too. However, while the costs for the various investment alternatives are fairly predictable, the benefits calculation methodology is not provided in sufficient detail to calculate a cost benefits ratio with any predictable confidence. Most of the benefits must therefore be considered as highly speculative; however, the utilities must invest in Smart Grid technologies if the regulations so require. So, where regulations are the driver for these investments, the benefits are immaterial since the costs will be covered in the rate base.

The fluidity of the Smart Grid concept was recognized by regulators, legislators, and the utilities, and led to the formation of an organization named the Critical Consumer Issues Forum (CCIF) in 2010, which issued a final report in July 2011[97]. CCIF decided to call the initiative Grid Modernization to differentiate it from "Smart Meters." CCIF established 30 principles covering cost/benefits, privacy issues, consumer protection, consumer education, and regulatory issues involving state and federal agencies. The members of CCIF recognized that the benefits of Smart Grid investments might be soft and therefore, concluded that Smart Grid projects should be given close scrutiny to establish that the cost/benefits ratio is sound.

3.2.5.4 PSE's Smart Grid Approach

The Washington State Legislature in WAC 480-100-505(3)(a) defines the "Smart grid function" primarily as a digital communication platform for information gathering, processing, and dissemination. The information is intended to enable the providers and users of electric energy to manage their use of electricity for increased efficiency in the use of electric energy; to detect

[95] PSE has a morning and late afternoon peak power profile. Therefore, PSE might be in a better position to provide charging power later in the morning if it is completed before the afternoon peak power period begins.

[96] Reference 23.

[97] Reference 24.

and manage events causing interruptions and disturbances in the system delivering electric energy; to integrate new distributed energy generators in the electric system; and to manage new loads such as electric vehicles. Reliability improvements are a major driver behind the initiative. The legislation requires electric utilities under the jurisdiction of WUTC to deliver a biannual progress report to WUTC on or before September 1. PSE filed such a report on September 1, 2010, and an updated report should be filed in September 1, 2012.

PSE has developed a Smart Grid initiative in response to the legislation. It defines PSE's initiative in three broad categories: 1) information technology, 2) customer information and energy empowerment, and 3) T&D infrastructure.

PSE was an early adopter of the Smart Grid technologies when it installed AMR in 1998, but the systems used by PSE were stand-alone systems that were not integrated with the rest of PSE's automation systems. In the information technology portion of PSE's Smart Grid initiative, PSE states that it will move toward an enterprise service-oriented architecture as it selects new applications with this architecture already imbedded. This will replace the largely point-to-point fixed communication network with local and wide area networks, which in PSE's terminology, becomes an enterprise service bus. Cyber security and interoperability issues are, according to PSE's document, issues being evaluated.

Part of these developments are an improved CIS, an OMS, and a DMS. PSE has already implemented a number of Smart Grid components and programs, but they are not fully integrated into one network or system. PSE is now evaluating a system to integrate these independent systems. Since the benefits of these Smart Grid initiatives are tentative and uncertain, PSE states that it will be working over the next several years to initiate or continue pilot projects that will allow it to effectively test the capabilities of new technologies and anticipate customer needs. In the T&D infrastructure, PSE's most fundamental Smart Grid initiative will be the continuation of upgrades to aging infrastructure and the completion of planned initiatives targeted to increase reliability for customers and reduce outage duration. The document submitted to WUTC in September 2010 contains a detailed capital investment plan for the 2011 through 2012 time period and also a 10-year horizon for additional investments. These plans have been reproduced in Table 4and Table 5.

Table 4. 2011–2012 Plan by PSE[98]

Information Technology/Systems	• Complete EMS upgrade to increase system security and reliability • Implement OMS: Complete evaluation by 2011, select vendor, implement with completion expected in 2012
Automated Metering	• Complete evaluation of migrating to two-way AMI technology from one-way AMR meters in 2011 • Pilot and initiate a phased conversion from AMR to AMI, based on evaluation and business drivers
Substation Internet Protocol (IP) Enablement	• Complete evaluation of pilot to migrate T&D substations to secure IP network • Continue extension of fiber optic cabling throughout T&D network
Customer Energy Use Information and Feedback	• Continue to review and evaluate proposals; consider the deployment of pilot programs to learn the potential savings and value proposition to customers • Continue implementation of home online tools with PSE customer base
Home Power Cost Monitor Pilot	• Complete pilot and evaluate results, such as energy savings, technical feasibility, and cost effectiveness • Based on pilot, determine potential broader deployment
Demand Response Pilots	• Evaluate current residential and commercial demand response pilots, including system performance and customer acceptance for demand response
Home Intelligence/ Automation	• Consider soliciting proposals for a pilot project
Prepay Billing System Pilot	• Consider soliciting proposals for a pilot project
Customer Energy Generation	• No specific technology changes, evaluations, or projects are anticipated in the next 2 years, however, PSE will continue to support customer adoption of small renewable generation • In anticipation of this rapidly growing program (9,000 net metered customers are projected by the end of 2015), evaluate and implement streamlined solutions: – Implement new customer interconnection process improvements – Expand renewable generation section of PSE.com website – Implement policy and process for interconnection for customer generation projects between 100 kW and 2 MW

[98] Reference 19, Appendix B

Electric Vehicles	• Update review of energy and capacity demands in latest IRP • Study impacts of early electric vehicle adopters on distribution levels and develop plan for changes to planning and customer service models to support mass adoption • Continue collaboration with major customers and public infrastructure in the region to support regional planning of transportation and utility infrastructure, and consumer information on location and use of charging stations • Evaluate the value to customers and the utility from timed or staggered charging based on actual data from early customers; pilot if positive economic case and communications standards and equipment are in place
Transmission Automation and Reliability	• Evaluate existing automatic transmission schemes for performance and determine the need for new schemes and/or modifications to existing schemes; select projects based on specific benefits and costs and available funding • Continue to upgrade aging/older SCADA systems in transmission substations
Distribution Automation	• Continue to monitor and learn from the distribution automation systems serving Microsoft • Evaluate and develop pilots in one to two select areas where reliability is an issue
Distribution Supervisory Control and Data Acquisition	• Continue SCADA installation; select projects based on specific benefit and costs and available funding • Install supervisory control of feeder breakers and ampere readings on all three phases of breakers at critical distribution substations
Recloser Installation	• Continue to install reclosers on overhead distribution circuits where customers would reliably benefit from the installation • Evaluate and pilot one recloser with communications for remote monitoring and control
Conservation Voltage Reduction	• Evaluate and develop plan for conservation voltage reduction program, and implement as budget funding allows

Table 5. Ten-Year Plan by PSE[99]

Information Technology/Systems	• Complete OMS-DMS-EMS-Meter Data Management System (MDMS) integration • Upgrade CIS • Implement enterprise wide GIS • Complete integration of MDMS to Outage and Engineering applications
Automated Metering	• Continue AMR-AMI conversion, as appropriate
Substation IP Enablement	• Based on pilot results, migrate T&D substations with DNP (Distributed Network Protocol) to a secure IP network. Upgrade substation remote terminal units from Vanguard, an older, proprietary network protocol, to DNP/IP standard protocol between the T&D substations on a secure IP network with point-to-point communications within the substations • Continue extension of fiber optic cabling throughout T&D network
Customer Energy Use Information and Feedback	• Continue to review and evaluate proposals; consider the deployment of pilot programs to learn the potential savings and value proposition to customers
Home Power Cost Monitor Pilot	• Expand application as appropriate, based on pilot evaluation and future applicability
Demand Response Pilots	• Expand application as appropriate, based on pilot evaluation and future applicability
Home Intelligence/ Automation	None
Prepay Billing System Pilot	None
Customer Energy Generation	• Continue to monitor consumer/market changes and technology advances for program enhancements and/or changes
Electric Vehicles	• Develop energy and demand forecasts based on already experienced adoption rates and needs • Incorporate electric vehicle loading and forecasts into distribution and transmission planning, and design standards where appropriate • If customer benefits can be demonstrated, scale a program in step with information technology communications and meter rollouts and customer demand

[99] Reference 19, Appendix B

Transmission Automation and Reliability	• Depending on project-specific benefits and cost, as well as available budget funding, continue toward the goal of having supervisory control of all automatically controlled switches • Continue to upgrade aging/older SCADA systems in transmission substations • Depending on benefit/cost and available budget funding, selectively replace aging components with modernized equipment that will facilitate Smart Grid adaptability
Distribution Automation	• Expand distribution automation in areas with high critical load and/or reliability concerns
Distribution Supervisory Control and Data Acquisition	• Continue expansion of functionality with the long-term goal of all distribution substations having SCADA with ampere readings for all three phases at the breakers; and supervisory control of the feeder breakers
Recloser Installation	• Continue expansion of recloser installation program and expand communications and monitoring capability depending on evaluation, pilot, and benefit/cost
Conservation Voltage Reduction	• Expand conservation voltage reduction program to appropriate locations where cost-effective implementation yields further energy savings

The first objective listed in Table 4 covers upgrading of PSE's communication system infrastructure. This is necessary since older systems, which are based on older telephone type technologies, are no longer cost effective or maintainable, and cannot accommodate the needs to communicate with a plethora of new devices used for monitoring and control of the power system and the installed equipment. The new systems are based on communication servers that operate through wide area and local area communication networks. Numerous new products include wireless devices requiring wireless access points. These new communication technologies are required to support almost all of the projects identified for the 2011 and 2012 time period.

The second major objective of the listed projects is geared to improving the reliability of the power system because PSE has not met SAIDI for the years 2007 through 2010. Automatic sectionalizing of distribution system feeders combined with automatic reclosing is a proven method to restore power to as many unaffected power users as possible after a system fault. When this is combined with supervisory control of the distribution system (Distribution SCADA), the operators are given the tools needed to diagnose system faults and to restore power to as many power users as possible before trouble shooters and repair persons are able to get to the fault location. This should, therefore, bring down the SAIDI number for PSE and hopefully bring it in compliance with WUTC rules.

The costs and benefits accruing to PSE and its customers cannot be assessed because the necessary information has been redacted from the available document describing PSE's Smart Grid Initiative Report.

The upgrading of PSE's communication system infrastructure is not expected to be finished in the first 2 years covered by the plan. The 10-year planning horizon anticipates further modernization of the communication and information technology infrastructure. In fact, communication systems are evolving at an accelerated pace. Thus, continued upgrading and replacement of outdated equipment can be expected to be a continuous task well beyond the 10-year horizon.

Improving reliability of the power system can also be expected to be a continuous requirement from power users and regulators. However, there are limits on how much the reliability of the power system can be improved by means of automation and improved fault information. Reliability improvements will also require replacing failing equipment and possibly putting the circuits underground where they are not affected by contact with trees or similar hazards.

A third objective emerging from the 2- to 10-year plan is the need for reducing the power demand when the source of the available energy is costly. However, the plan also anticipates new demands such as those expected if use of electric vehicles expands. The plan also anticipates more distributed generation sources in residential areas. These developments are in their infancy and the net effect on the demand for electric power is still not well known.

The review of PSE's medium-term plan has been performed. This plan defines PSE's required investment needs over the next 10 years to ensure that PSE can reliably supply electric power to its customers. This review, the results of which are described below, address both generation and transmission system needs.

3.2.5.5 Smart Grid Implementation in Bellevue

As Bellevue moves with the rest of the country from the conventional electric delivery system toward eventual Smart Grid architecture, incremental but critical system changes will be an important component of the process. The Smart Grid is driven from the utility perspective by the potential for peak power reductions through switching off and on customer loads. It is also perceived by the power consumers, utilities, and businesses as a need for information and the potential for new business opportunities: the utility needs a tally of each customer's energy use for billing; a customer desires near-real-time pricing of electricity to make decisions about when to use energy; the utility desires timely power use data to set dynamic pricing and drive its peak-shaving program during periods of high demand, and issues commands to disconnect certain loads from the system; a customer wants proper credit for any net distributed generation output that is supplied to the grid, including energy from electric vehicles; and other business enterprises perceived opportunities for selling application software or products that will help consumers with the decision making process. To support these needs, a communications backbone is an integral necessity to any Smart Grid layout. However, the promised Smart Grid benefits might be diminished if the electricity supply at the customer's meter is not highly reliable.

PSE already have the ability to read the energy meters remotely. The Smart Grid technology does not provide any added value with regard to meter readings. However, basic improvements to the electrical power system will be required to take advantage of the benefits, which should be available through the Smart Grid technology mix. The expected enhancements that the

Smart Grid promises to add to the customer experience will potentially enable the utilities to manage system and circuit overloads by reducing the load flows that might enable the utility to avoid a line overload and an outage. This requires investments in control systems on the utility side as well as the user side of the meters for load control. PSE's investment plan anticipates such investments on the utility side of the meters.

One of the basic components of the Smart Grid concept is the ability for the power company and the end user's meter to engage in two-way communications. While the use of AMR was important in its day, the purpose of AMR was to allow remote meter reading without sending out a person to do that job; the communication was still one-way from the meter to PSE. If real-time pricing of electric power and the ability to control customer loads by switching loads on and off proves to be beneficial, then PSE will need to develop a deployment approach for migrating from the AMR concept to an AMI, which consists of a communications backbone and smart meters that can supply frequent power use data to PSE, and that also accepts commands from the DMS for the purposes of controlling loads in the home or place of business. The advantages to this type of operation might be beneficial to both Bellevue's power customers and PSE, if PSE will be able to offer lower rates in return for the ability to disconnect certain appliances during peak use hours. Such peak shaving will help PSE to more effectively balance the energy supply and demand for the City.

PSE is only in the earliest planning stages with regard to smart meter deployment, and the timing will depend on if the cost benefits of the Smart Grid technology is attractive to the consumers. At the present, it appears that the first smart meter installations operating over an upgraded communications system could be several years away.

Distributed generation within Bellevue could become a key component of its Smart Grid architecture. If distributed generation systems become more widespread, then such systems might become another tool for utilities to control peak power flows. This might even involve the use of stored energy in electric vehicles that are plugged into the system.[100]

Action items for the City:

- The City should engage with PSE to ensure that the high value portions of the Smart Grid technologies are implemented in a timely manner for the benefit of the power users in the City.
- At present, there is no plan by either the City or PSE to make the needed investments to support the use of electric vehicles in the City. Since charging of electric vehicles is expected to be a function that should be supported by the Smart Grid technologies, the City should open a dialog with PSE to address issues related to electric vehicle charging systems

[100] Rogers, K.M., et al. 2010. Smart-grid-enabled load and distributed generation as a reactive resource. IEEE Innovative Smart Grid Technologies Conference. January 2010.

3.3 Growth Scenario Review (Long Term)

3.3.1 Study Approach

A review of PSE's long-term plan has been performed. While this review is similar to the medium-term review, the uncertainties associated with long-range forecasting are substantial. In particular, the impact of new legislations associated with global warming issues might cause drastic changes in the fuel mix available to electric utilities and the price of fuels. Other environmental regulations associated with clean air and water can also cause disruptions in the supply of power. PSE takes these uncertainties into account as much as possible but cannot commit to making new investments to meet unknown requirements. The results of the review are discussed below.

3.3.2 New Transmission Access beyond the Year 2020

Chapter 7 of the 2011 IRP discusses the needs for reinforcement of PSE's electric transmission system during the next 10 years, from 2011 through 2021. No part of the plan addresses needs for a 20-year planning horizon, which might be appropriate because the uncertainties over such a long time horizon are substantial. Also, it should be possible to complete transmission line projects as needed over a 10-year time period. Although the needs for power transmission lines beyond the year 2020 are not possible to assess with any certainty, it can be assumed that it is not going to be easier to build overhead, high voltage transmission lines in the future than it is today. The corridor along Interstate 5 is likely to remain heavily loaded since it is the interface between British Columbia and the lines along the Pacific Coast toward California.

PSE states in the IRP that, presently, the region often suffers from transmission system constraints resulting in curtailment of firm contractual transmission rights. This is likely to remain a problem. The Columbia River Treaty also adds to the congestion of the transmission lines in and around the Puget Sound until the year 2024 and possibly beyond.[101] These issues have to be addressed in the 2013 plan.

3.3.3 Resource Plan for the Time Period Beyond 2020

The estimated demand for the time period beyond 2020 is much less reliable since major disturbances or uncertainties in the availability and price of fuel, population growth (demographics), technology innovation, legislation, etc. are likely to impact the need for and use of electric power.[102] Therefore, this portion of the plan has to be considered as speculative. Revisions on a biannual basis produce a rolling plan that will over time lead to decisions for new investments beyond the year 2020.

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[101] Reference 16.

[102] The result of the oil crises in the 1970s was the loss of the U.S. steel industry. Further erosion of U.S. manufacturing has happened over the last few decades as a result of growth of manufacturing capacity in emerging, low labor cost, third world countries. Such changes are difficult to predict, which makes long range forecasting highly uncertain.

As seen in Figure 51, the plan indicates a potential shortfall in power capacity of over 4,000 MW by the year 2031. This is only an indication of the possible need to build or acquire new power plants beginning in the year 2020 if the trend persists.

3.3.4 New Power Sources

A review of the PSE IRP has been performed to determine PSE's needs for new power sources to meet the current IRP mid-range forecasts. The results of this review are discussed below.

As is obvious from Figure 51, PSE needs to continue to acquire new power sources beyond the year 2020 to cover the gap between the presently owned or available power sources and the expected demands for power. However, the uncertainties facing the industry make it extremely difficult to forecast the actual needs that far into the future. The macro-economic situation in the near term is difficult to foresee and possible legislation associated with global warming and carbon-dioxide legislations are just two legislative unknowns. Since there would be time to put new plants in place with a 10-year-lead time, the details for how to meet the demands for electric power beyond the year 2020 are left to future planners. The plan to be issued in 2013 will cover only a small portion of the planning horizon past 2020. This plan will also have to cover any needed new transmission lines required to bring the power into PSE's service territory.

3.3.5 Fully Built-Out Downtown

Current plans for the ultimate build out of the electrical system feeding the Downtown anticipates a growth of the power system demand from about 100 MW to 200 MW over the next 20 years. The basis for the fully built-out load growth for Downtown and Bel-Red is provided in City and PSE planning information.[103] Additionally, Exponent reviewed the substation current peak loading data for the Bellevue substations provided by PSE along with the PSE loading guidelines document[104] to determine the need for additional capacity to support the build-out scenario. The existing system needs strengthening because one of the main 115 kV lines feeding Downtown passes through the Clyde Hill substation, which already carries about 130 MW. This loading is close to the maximum value allowed under PSE's loading guidelines. This strengthening of the power system feeding Downtown requires cooperation between PSE, the City, and the business community in the Downtown. Based on the current growth models for the Bellevue area, additional capacity will be needed. The following additions are required by the growth plan:

- A switching station on the Sammamish to North Bellevue line is needed to provide a third transmission line to feed power into this area in order to be able to handle the full 200 MW for the Downtown.

[103] References 36 and 37.

[104] Reference 38

- Four transformer banks to support the build-out of the Downtown. These banks are required as the City reaches various growth thresholds in the Downtown. An additional bank will be required for each 25 MVA load increment. It is anticipated that two of the banks may be required prior to 2020 and the other two banks sometime in the future as the Downtown reaches its growth capacity.

- Two transformer banks to support the expected growth and build-out of the Bel-Red area. Again, an additional bank is required for each additional 25 MVA of additional load. It is anticipated that expansion in this area will require one bank within the next 10 years and one in the long-term horizon.

- One to two transformer banks to support growth in the Eastgate and Somerset areas and to improve overall reliability. Depending on the economic recovery, this addition may be required in the short term.

- Upgrade of the 115 kV lines that feed the City to support higher load growth in the region. As stated previously, the need for upgrade of these lines is expected to be required in the 5 to 10-year time frame.

- A third transmission feed into the one of the north side substations is required to support the additional electric demand in the Downtown.

Table 6 indicates a requirement time frame for these additions. The purpose of the time frame is to provide the City with an early warning system for engaging PSE in discussions on these capacity additions. Based on recent experience, it is assumed that these discussions are required 3−5 years in advance of these needs. Recent experience with T&D projects indicates that:

- Transformer additions require 18−24 months to complete from start of engineering to operation. Additional time is required for planning and permitting.

- Line projects may require 4−5 years from the start of engineering to completion since permitting of lines typically requires significant engineering to be completed before the formal permitting process proceeds.

- The City should begin discussions with PSE in regard to the impact of electric vehicles with the associated need for charging stations in the Downtown area of the City.

- The City should initiate discussions with PSE with respect to PSE's plans for implementation of a so called Smart Grid to understand the potential costs and benefits of PSE's Smart Grid initiative.

Table 6. Major Project Roadmap

Capacity Requirement	Action	Potential Need Date	Initiate Early Planning Time Frame
Downtown			
Growth to 125 MVA	Add transformer bank	2016	2012
Growth to 150 MVA	Add transformer bank	2020	2016
Growth to 175 MVA	Add transformer bank	2026	2022
Growth to 200 MVA	Add transformer bank	Post 2026	Unknown
Bel-Red			
Growth to 20 MVA	Add transformer bank	2018	2012
Growth to 40 MVA	Add transformer bank	2026	2022
Somerset/Eastgate			
Growth/Reliability	Add transformer bank	2018	2012
115 kV System			
50 MVA Need Downtown/Regional Growth	Upgrade 115 kV line	2018–2022	2012
Additional 50 MVA Downtown	Add third transmission feed from north	2020–2024	2015

3.4 Future System Assessment Recommendations

The future system status has been reviewed using the future plans for growth in Bellevue, PSE's long-range planning, and potential technology innovations. Based on this review, a set of findings and recommendations is provided to the City of Bellevue for their use as an informed stakeholder.

Recommendation Future 1: Energy Efficiency Programs

Finding: PSE's long-range plans indicate a significant reliance on energy efficiency for management of the peak electric power demand.

Reliability Actions: Support for Long-Term Power Supply

Recommendation Future 1: The City should lead the electric energy efficiency effort to assist PSE in reaching its peak electric power demand goals to avoid using or building new peak electric power plants. Electric energy efficiency programs require active outreach to the customers and citizens to support various energy efficiency initiatives. The PSE long-term plan has a large reliance on electric energy efficiency.

This is a longer-term issue that will be included in future PSE IRPs. The City should remain active in the IRP process and should begin to understand potential long-term impacts of this strategy.

Recommendation Future 2: Smart Grid Initiatives

Finding: PSE is initiating Smart Grid programs to comply with WUTC requirements.

Reliability Actions: Enabling of reliability impacts of Smart Grid technology.

Recommendation Future 2: PSE has identified a series of Smart Grid technology projects that are being considered over the next 2 years. These projects include a range of programs from base infrastructure required to enable the Smart Grid to specific customer-related efforts. Several projects that support development of the infrastructure are currently underway:

- Upgrade of information technology systems
- Upgrade SCADA in transmission substations
- Distribution SCADA on feeder breakers
- Extension of fiber optic cabling through T&D system.

These programs represent upgrades to the PSE infrastructure that are being undertaken on a system-wide basis. Additional programs to enable customer interface applications will be needed. These technologies have been discussed in other recommendations.

An issue with Smart Grid implementation is that PSE must review customer interface applications on a system-wide basis and Bellevue may have different needs and requirements than other parts of the PSE service territory. Security of these communications systems will become a major issue that needs to be resolved before major investments are made in the new technologies.

Therefore, the City should review the overall PSE plan and determine their level of support for the various customer initiatives that would be appropriate for the City to provide. The types of initiatives to be considered are those relating to customer energy management, demand response, and home automation. These technologies are enabled by significant communication system upgrades, but allow for consumers to have greater control over energy usage and expenditure.

Recommendation Future 3: Major Project Planning (see Recommendation Role 2 also)

Finding: PSE maintains a plan for expansion of the system in Bellevue to support growth of the City and the region. However, as the lead time to permit larger projects (required to add capacity or reinforce the City infrastructure) has grown, it requires that the City understand the projects from a more detailed perspective than just a conceptual framework.

Finding: There is the potential for several of the growth-related projects to occur within this decade. The specific projects for consideration are upgrade of the 115 kV lines, additional capacity required for the Bel-Red and Somerset/Eastgate areas, and additional capacity requirements Downtown.

Reliability Actions: Conduct major project discussions well in advance of permit applications to ensure sufficient lead time to permit larger projects (required to add capacity or reinforce the City infrastructure).

Recommendation Future 3: It is recommended that the City engage PSE in an annual planning workshop around future projects with the intent of understanding the requirements from a City perspective. The Comprehensive Plan includes an electric system plan that can serve as the basis for the annual workshop. The workshop should focus on the following items:

- Current growth projections and electric power use in Bellevue
- Review of current plan applicability (Figure UT.5a from the City of Bellevue Comprehensive Plan)
- Update of the current plan
- Develop actions for capacity projects required to initiate siting and permitting activities within the next 2 years.

An outcome of the workshop should be an updated plan for inclusion in the Comprehensive Plan (if required) and an action plan to move designated projects forward into siting analysis and/or planning.

As a minimum, the following capacity additions have been identified as being needed within the next 5 to 10-year time frame. These capacity additions are based on the proposed growth within Bellevue and an assessment of current loadings on the Bellevue substations.

- Upgrade of existing 115 kV lines to 230 kV
- Addition of transformer banks to support expected growth in various areas of the City (Downtown, Bel-Red, and Somerset/Eastgate)
- Addition of new 115 kV lines to reinforce the overall electric system.

Based on recent Exponent staff experience with T&D capital projects, capacity additions of this magnitude typically require the following project execution times:

- Transformer bank additions require 18−24 months to complete from start of engineering to operation. This project time frame is based on the major material long-lead times (which have been increasing), and typical engineering and construction times. This time frame can be different based on difficulty in working at existing stations or permitting new stations. Also, additional time is required for planning and permitting.

- Line projects may require 4−5 years from the start of engineering to completion since permitting of lines typically requires significant engineering to be completed before the formal permitting process proceeds. The time frame for these projects is dependent on the length of the line segment, the number of jurisdictions involved, and the number of permits required (federal, state, and local). Line projects often require engineering to be completed in order to satisfy permit applications so that these projects have a longer time frame than substation projects.

Recommendation Future 4: Long-Range Planning

Finding: Both Bellevue and PSE work with various developers and companies to identify new potential facilities in Bellevue. There is an opportunity to share and communicate the results of these planning activities. This exercise relates to longer-term issues that are expected to be addressed in the future.

Reliability Actions: Coordination of growth planning and major project activities.

Recommendation Future 4: While information is shared for the IRP, and to the extent that information can be shared, it is recommended that a more formal meeting (annually) be held to ensure that all of Bellevue's needs are identified to PSE and that both organizations are coordinated regarding future load demand. This information sharing can also be included in the annual planning meeting.

The City and PSE should synchronize their growth projections for the City by exchanging information on expected projects, expected timing of projects, and coordination actions required by PSE and the City to address these projects. This exchange is meant to be longer-term planning and well in advance of any specific permitting or development activities.

4 Role of the City of Bellevue

4.1 Study

4.1.1 Study Scope

The Role of the City assessment was performed to answer the following question: "what opportunities are available to the City to work with PSE, regulators [WUTC, FERC], and other stakeholders to ensure the needs and expectations of Bellevue's residents and businesses are met relative to the reliability of the power supply?"

4.1.2 Study Approach

The Role of the City assessment was performed in the following steps:

- Evaluation of potential interactions with WUTC and other government agencies as it relates to the City's ability to inform decision-makers or to advocate for policy change
- Evaluation of City's interaction with PSE around planning and permitting relative to influencing electric system reliability in Bellevue
- Review of transparency of operations relative to improvements in communication between PSE and its customers as it relates to reliability.

4.2 Enhance Role of City as an Informed Stakeholder

4.2.1 Regulatory Agencies

4.2.1.1 Study Approach

Prior to discussing the opportunities for Bellevue to interact with regulatory agencies, it is important to understand the regulatory framework under which PSE operates the electric power system and the regulatory framework as it affects the City. A brief summary of the regulatory requirements and their impact on reliability is provided below.

4.2.1.2 Washington Utilities and Transportation Commission

WUTC provides oversight to electric utilities through regulations codified in the WAC Chapter 480-100. As noted in WAC 480-100-001, the purpose of these regulations is "to administer and enforce chapter 80.28 RCW by establishing rules of general applicability and requirements for consumer protection, financial records and reporting, electric metering, and electric safety and standards." The principal statutes that define WUTC's authority and responsibility with respect to electric utilities are found in RCW Title 80.

In determining the opportunity for the City to interact with WUTC, Exponent reviewed the responsibility of the agency to oversee the operation of electric utilities regulated by the agency. These requirements were then reviewed as they relate to PSE activities. Relative to electric system reliability, there are several requirements that are highlighted here:

PSE-Related Activities

- PSE is required to publish and communicate rates for electric power delivery through the filing of tariffs and rate schedules with WUTC (WAC 480-100-028 and WAC 480-100-103). Any changes to these tariffs or rate schedules must be presented at public hearings before WUTC and are subject to public hearings (RCW 80.28.020 and WAC 480-100-194). This requires PSE to present its basis for the proposed increases (for its investments and costs for providing services) to WUTC and to justify these expenditures as prudent since these expenditures are the basis for the increases and the means of PSE recovering their investment. The proposed changes are then reviewed by WUTC staff and a decision regarding the proposed changes is issued. While this process introduces risk to PSE's investment plans, the process is not expected to significantly alter PSE's investment program.

  This process of utility commission oversight is common to regulated utilities in the United States. In the case of PSE, they present their request for rate increases after investments are made so they are recovering expenses after they have been incurred. In other states, the rate case proceeding precedes the investments and the level of investment is approved prior to execution of projects. In the case of PSE, this requires that their investments (e.g., capital projects) be considered as prudent uses of capital across their entire system.

- PSE is required to have a rate structure that provides the same rates for similar services. This requirement is based on RCW 80.28.80. This requirement establishes a basis that a utility cannot provide preferred service and that service must be provided on a non-prejudicial basis except for a few special exemptions provided in the RCW. This requirement means that PSE must select projects to maintain their electric system assets from an overall system perspective.

- PSE is required to submit annual reliability reports that provide the service performance to its customers (WAC 480-100-398). This report highlights the current performance as well as actions that PSE will take to improve performance. This report addresses the entire service area. PSE indicates system circuits of concern (top 50) and identifies specific actions for these circuits. For 2010, there were no circuits identified in the Bellevue area (although Lake Hills-23 was on the list in 2009) (Reference 4).

- Through RCW19.285, the state of Washington has required that utilities meet a portion of their generation requirements through the use of renewable technologies. The state has required that at least 15% of generation come from renewable sources by 2020. The intent of this requirement is to encourage the use of renewable energy sources and energy efficiency in the state of Washington. This requirement affects reliability in the sense that PSE must develop a generation mix that satisfies its load demands and its renewable energy portfolio. In the future, as renewable energy sources and distributed energy sources become a bigger power source and a more local source, there will be a challenge to maintain the T&D system within acceptable voltage levels.

- WUTC (WAC 480-100-238) requires utilities to submit an IRP that is intended to present how a utility will meet its system demand and what the mix of generation sources will be. The IRP is required to examine alternatives that allow for meeting future demand at the "lowest reasonable cost." Utilities are also required to address conservation relative to energy reduction from energy efficiency and other means. The requirement is to submit the IRP on a biannual basis.

  PSE provides an IRP defining its strategy to respond to future load scenarios. The current IRP has been referred to previously in Section 3 in discussing future system status.

- Requirements for delivery of power are specified in WAC 480-100-368 and -373 for system frequency and voltage, respectively. The requirements state that the system must be operated at a frequency of 60 cycles per second under normal conditions and the voltage (depending on service class) must be maintained within ±5% of the standard voltage on the distribution feeder. There are additional requirements related to both utility and customer actions to control voltage fluctuation.

  This requirement directly relates to the issue of power quality. PSE is required to deliver voltage within the specified range. For customers who require a tighter band on voltage fluctuations, there are standard technologies employed by the end user at these sites to maintain the required voltage stability. Typically, information technology and manufacturing plants most often use site-specific technologies to control voltage that may interrupt their operations.

City-Related Activities

- Through RCW 35.96.040, the state of Washington specifies requirements that allow cities or towns to create local improvement districts and to levy and collect special assessments against the real property benefitting from the conversion of overhead facilities to underground facilities. This requirement directly relates to the funding mechanism required to convert existing overhead facilities. Issues regarding the conversion of overhead lines to underground were presented in Section 2.2.6.4.

- Through RCW 36.70A, the state of Washington requires cities and counties to develop comprehensive land use plans to govern growth management in their jurisdictions, if they are required or choose to plan under RCW 36.07A.040.
- Through RCW 80.32, the state of Washington allows cities to establish franchise agreements with utilities relative to use of city rights-of-way (public roads, streets, and highways).

There are additional requirements in the state of Washington statutes and WUTC regulations that govern interconnections to the electric system, requirements for the renewable portfolio, and purchase of power from qualifying facilities.

4.2.1.3 Western Electricity Coordinating Council

The second organization with oversight responsibility is WECC, which is chartered with ensuring the reliability and security of the bulk electric system in the Western Interconnection. Since PSE has limited bulk transmission assets, their involvement with WECC deals with coordination of their transmission lines with the WECC area. PSE interacts with WECC for operations of its transmission lines at 100 kV and above. WECC provides requirements for operations and maintenance of the transmission system to ensure the reliability, stability, and security of the transmission system in the western United States and Canada. PSE involvement with WECC is mostly from an operations, maintenance, and protection standpoint to ensure that its system operates and coordinates planning with other regional entities. WECC develops standards for the western region based on review and application of NERC reliability standards which defines requirements to maintain reliability of the transmission system in the United States. WECC activities are focused only on transmission and do not reach into the distribution system within Bellevue or other parts of the PSE service territory. However, this interface is important from the transmission standpoint where events on the transmission system can result in significant wide-area outages.

4.2.1.4 Analysis

From a WUTC perspective relative to electric power, cities are considered as any other member of the public. This means that Bellevue has access to the published tariffs and rate schedules of PSE and has the ability to participate in public hearings and to offer comments and opinions relative to these hearings. Therefore, Bellevue’s primary interaction with WUTC is one of being an active participant relative to changes in laws and tariffs that may affect electric system reliability in the State of Washington.

From an overall regulatory perspective, the City has the right to execute franchise agreements with companies that provide utility services to the City. These items are discussed in Section 4.2.2.2.

From the perspective of WECC, Bellevue has no real involvement with this group since it deals with issues on the transmission system (and large generation). WECC, however, does provide a source of information relative to electricity planning in the region and provides short- and long-term views of the electric transmission system. Their planning documents identify needs of the system moving forward and will provide Bellevue with an independent assessment of potential transmission needs in the area that may affect assets providing service to Bellevue or that are located in Bellevue.

4.2.1.5 Recommendations

There are potentially two areas of involvement by Bellevue relative to WUTC:

- Since WUTC operates and oversees all regulated utilities, any changes in fundamental requirements must be driven by state law and enforcement by WUTC must be consistent and fair among all regulated companies. Therefore, Bellevue's involvement in this aspect is one of informing lawmakers and commissioners regarding matters that affect reliability. However, matters affecting the electric system must be viewed in a global rather than a local context.

- Bellevue does have the opportunity to comment or participate in matters directly affecting PSE and their interaction with WUTC. The City may choose to support or oppose measures for investment brought forward by PSE that support its overall City goals for electric system reliability and service. Again, PSE has to propose its plans to WUTC on a system-wide basis, but Bellevue has the ability to support and advocate for initiatives that meet its goals and objectives.

From an overall regulatory perspective, interaction with the regulatory agencies provides Bellevue with a means of keeping current on plans for the electric system and advocating for projects that meet Bellevue's objectives.

4.2.2 Puget Sound Energy

4.2.2.1 Study Approach

Bellevue's primary involvement in electric system reliability is through its interaction and collaboration with PSE. There are several areas where Bellevue is actively involved with electric system activities by PSE. The interaction between the City and PSE relative to specific reliability initiatives and outage performance was discussed in Section 2. The major areas of interaction discussed here are planning, permitting, and emergency response.

4.2.2.2 City Policies

Bellevue establishes policies for utilities in the Utilities Element of the Comprehensive Plan[105]. The City provides its long-term vision and plans in its Comprehensive Plan, which provides goals, policies, and plans for all areas and aspects of City operations. The Utilities Element addresses many activities relating to electric reliability, including:

- A high level plan for utility capacity expansion to meet City and regional needs and to guide planning and decision-making
- Coordination of public and private trenching activities (related to the potential for undergrounding opportunities)
- Notification to the City prior to vegetation management in the City rights-of-way
- Required undergrounding of all new electrical distribution facilities
- Encouragement of consolidation of facilities
- Facilitation of conservation and environmentally sensitive energy sources
- Encourage communication with utilities, WUTC, and the City about cost distribution and undergrounding of electric distribution lines.

All of these policies have the potential to impact reliability. Additionally, through the Franchise Agreement between the City and PSE, the City provides requirements for work in the City rights-of-way that are intended to reflect the policies of the Comprehensive Plan. Based on a review of these documents, the City is influencing reliability through its planning and permitting process, its vegetation management policies, the ability to underground new facilities, and coordination of activities to take advantage of joint utility efforts. In the longer term, renewable and alternate energy sources and conservation will factor into the overall electric energy picture in Bellevue.

The recommendations provided in Sections 2 and 3 are consistent with the policies of the Comprehensive Plan. The recommendations are based on focusing the City's efforts on areas that will drive improvements in reliable service to existing and new members (business and residential) of the community, that satisfies the City's goals, and that understands the requirements of PSE as a regulated utility. The recommendations are provided to support City reliability through improved system design (redundancy), expanded use of automation and information technology, and improved communications between the City and PSE on matters affecting reliability and growth.

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105 Reference 26.

4.2.2.3 Planning

Both Bellevue and PSE engage in planning for the City. However, the planning needs for each organization are focused on different areas and concerns. Bellevue planning is required to address services and land use planning across all aspects of city operations, such as impact on land use, rights-of way, roadways, water and sewage, and coordination of projects by other utilities (electric, gas, and telecommunications). Therefore, planning by Bellevue involves the following:

- City growth projections including major facility and capital projects
- Forecast and plans for land use
- Forecast and plans for roadway additions and changes
- Forecast and plans for utility (water, electric, gas, telecommunications) additions and changes
- Forecast and plans for parks and public areas.

PSE focuses on planning for electric and gas system operations. PSE obtains its growth plans and projections from interactions with its various customers including cities, developers, companies, and facility owners. PSE and Bellevue share many of the same customers when it comes to planning for growth in Bellevue.

From the perspective of electric system planning, there are two main elements:

- Overall long-term growth planning to identify the potential for growth in Bellevue and to identify the need for additional electric system capacity.
- Medium-term tactical planning for specific projects that affect the electric distribution system in Bellevue as well as the PSE-owned transmission lines. The long-term plan is based on growth projections in the PSE service territory (Bellevue and surrounding areas) that impact the need for additional service to various areas of the City. The Comprehensive Plan Utilities Element Figures UT.5 and UT.5a present the current view of potential plans for electric expansion in Bellevue to meet future needs.

Discussions with staff in both Bellevue and PSE indicate that the overall growth plan is developed based on individual discussions with prospective developers and then later meetings are held between PSE and Bellevue to ensure that PSE has input from Bellevue relative to preparing their IRP. This level of planning is one of the means that PSE utilizes to project growth and to develop system plans to support growth. Since these are longer-term plans to identify future needs, the major need is to coordinate the results of the planning activities to ensure that PSE is informed by City input relative to growth for inclusion in its long-term planning process.

The medium-term tactical planning is directed at potential projects that may need to be performed in Bellevue on existing or new locations. Typical maintenance or replacement projects are handled through the normal permit process. PSE performs ongoing assessments and studies of its electric system to ensure that the system is capable of handling current and future demands. The PSE plans are based on their projections for future growth in Bellevue and other parts of their system. These medium-term tactical projects are also part of the IRP. The ability to turn the medium-term tactical plans into real projects varies by size and type of project. The projects subject to tactical planning are large expansion projects (substation expansions, new feeders, substation connections) that require significant lead-time to proceed to an actual project. Based on the discussion in Section 3, there will be a need for new facilities as the City grows and reaches its build-out limits.

Bellevue has entered into a Franchise Agreement with PSE[106] that outlines requirements for PSE operation, construction, and support of facilities in Bellevue. The Franchise Agreement outlines the requirements for the various types of projects performed by PSE. The Franchise Agreement and the City Comprehensive Plan Policies include requirements that call for siting reviews of the larger capacity projects. Based on discussions with staff at PSE and Bellevue, the review and update of the utility growth plans in the Comprehensive Plan requires review and update. Since these capacity expansions represent large and complex projects, and given the significant growth expectations of the City, a regular update of the plan is appropriate to ensure that the City and PSE understand the requirements for future growth.

4.2.2.4 Permitting

Once a project is ready to proceed, it then enters the permitting process. For major projects (including those on sensitive site locations per the Comprehensive Plan), the following steps are typically required:

- Pre-application meeting
- Siting analysis that must include three alternatives
- Tentative agreement on an alternative
- Submittal of the application
- City recommendation
- Hearings and appeals, if required
- City Council decision
- Permit issued.

The typical time frame for these types of projects (from initial request to permit) is approximately 3 years and can be longer. Typical smaller projects follow a similar permitting

[106] Reference 27.

process but start with submittal of the application, and the process proceeds in a quicker manner. If the project is on the public right-of-way and is covered by the Franchise Agreement, then issue of the permit is handled through the Franchise Agreement and does not require City Council approval.

4.2.2.5 Analysis

Based on discussions with Bellevue and PSE staff, observations relative to the planning and permitting process are:

- There is good agreement that both parties understand the permitting process and that working relations between the parties is good. However, there is sometimes a need to get new PSE contractors to more quickly understand the process.
- Complete information in the permitting process results in a more routine permit process. Incomplete information tends to slow the process.
- For larger projects, more complete siting analysis information on the alternatives (specifically impacts and mitigation plans) will improve the permitting process.
- There is more public interaction and comment for any large projects, especially for aboveground infrastructure.
- The PSE tariffs are clear and understood by the City relative to services provided under tariff. When multiple non-City utilities are involved in a project, all have Franchise Agreements, and there is some negotiation required to determine who pays for the services depending on the project initiator.
- Future projects are understood at a conceptual level, but the details are not fully appreciated until the permitting process is initiated.
- Coordination between the various utilities requesting right-of-way work could be improved from a planning perspective so that each utility can plan for these opportunities.

4.2.2.6 Recommendations for PSE Interaction

The assessment indicates that there are opportunities to improve the overall knowledge sharing and coordination in the planning and permitting process. While the interactions between the organizations are good due to proximity and history, much of the interaction is based on informal communications. The following recommendations are provided:

- It is recommended that the City engage PSE in an annual planning workshop around large future capital projects. This is the same recommendation that is defined in Section 3. The outcome of these workshops should be an action plan to move projects forward. The intent of this recommendation is to have these major project discussions well in advance of permit applications. PSE has developed and maintains a long-term system planning strategy relative to the electric power system. This plan is generally represented in the IRP. However, as the lead time to permit larger projects (required to add capacity or reinforce the City infrastructure) has grown, it requires that the City understand the projects from a more detailed perspective than just a conceptual framework.

- Both Bellevue and PSE work with various developers and companies to identify new potential facilities in Bellevue. While information is shared for the IRP, and to the extent that information can be shared, it is recommended that a more formal meeting (annually) be held to ensure that all Bellevue needs are identified to PSE and that both organizations are coordinated regarding future load demand. This exercise relates to longer-term issues that are expected to be addressed in the future.

- There are opportunities for multiple utilities to take advantage of projects being performed by one of the utilities. This is a coordination function that is best captured by the City. It is recommended that the City engage their utility partners to identify new projects (both large and small) to attempt to maximize projects in the rights-of-way. This planning activity is intended to take place in advance of permit applications so that the utilities can plan these projects into their annual work. This action also represents a potential means to advance undergrounding of circuits if PSE can take advantage of trenching to add conduits for future use.

4.2.3 Transparency of Operations

The transparency of operations is focused on the communications between PSE and its customers during emergency and outage events. The City has a role to play as a representative of the community. However, PSE has also provided transparency in its operations through the information provided around its various business processes, projects, and plans.

4.2.3.1 Emergency Planning

The emergency response programs are well-defined for the both the City of Bellevue and PSE in their respective policies and procedures. The City of Bellevue maintains its emergency response program in its Emergency Operations Plan.[107] The plan supports and is compatible with King County and state of Washington emergency plans, the National Response Framework, and the Regional Disaster Plan for Public and Private Organizations in King County. Bellevue has adopted the National Incident Management System (NIMS) as the basis for incident management. The plan includes roles and responsibilities for the City departments and also discusses non-governmental agency support. In this case, PSE is identified as an

[107] Reference 28.

organization that will provide support during emergency events when appropriate. When requested, PSE will assign a liaison to the EOC, if available. However, PSE does assign a liaison to the King County Emergency Coordination Center (ECC) if a more regional emergency is called. Bellevue has also implemented programs for first responder "GETS" cards that provide priority access through the phone system. A HAM radio system is employed through the Amateur Radio Emergency Service to address situations where phone towers are down and normal (cell) phone communication cannot be used.

PSE maintains its emergency response program in its Corporate Emergency Response Plan.[108] This document outlines how PSE addresses emergency operations for both its electric and gas systems. Similar to Bellevue, PSE maintains an EOC and is in the process of adopting the NIMS protocol. Some key aspects of the PSE Emergency Response Plan include:

- An electric emergency is defined as:
  - 12 distribution circuits out in one region and escalating
  - 30 distribution circuits out system-wide and escalating
  - Poor weather conditions (wind, snow, ice) predicted
  - Earthquake or other hazardous conditions.
- PSE's overall response strategy is summarized as:
  - Restoration priorities are assigned for each region.
  - Focus on correcting problems that can be fixed quickly and restore the greatest number of customers.
  - Restore first and then repair (based on conditions of the damage). Damaged sections may be de-energized and service may be restored up to the point of damage.
  - Schedule and complete the repairs.
  - Facilities are generally restored in the following order: transmission, distribution substations, distribution feeders, and individual service. PSE maintains a more detailed list in its Corporate Emergency Response Plan document.
- PSE maintains a list of critical facilities and accepts municipality identification of critical facilities. PSE also maintains a list of locations that require priority for medical reasons (nursing homes, individuals).
- PSE maintains someone onsite at the King County ECC to coordinate on regional events.

[108] Reference 29.

- PSE has defined contacts as liaisons with Bellevue even if they do not staff the Bellevue EOC.
- PSE has established agreements with other entities, including their subcontracting partners, to provide resources in an emergency. This includes a Western Region mutual assistance agreement for support from other utilities outside of the area to assist in restoration and repair in a major emergency (such as the 2006 storm event).
- PSE also employs a HAM radio operations system in the event that normal phone service is not available.

The Bellevue and PSE EOCs are similar, but they serve different functions. The PSE plan is related to their service territory and the PSE EOC may be activated without Bellevue needing to activate its own EOC. Similarly, the Bellevue EOC focuses on events in Bellevue, and depending on the emergency conditions, may open without PSE having to activate its center. However, in all cases, there are established interfaces within each organization to provide communication during an emergency. Additionally, both Bellevue and PSE participate in regional emergency planning exercises and have significant information on their websites regarding emergency response.

There are several coordination actions required in order to recover from an electric system emergency outage. Bellevue indicated that they have provided a priority list of critical facilities to PSE so that these are known in advance. Another issue centers on coordination of local city police and fire departments to support PSE crews in getting access to streets and areas to provide assessment, restoration, and repair services. There currently is no formal protocol for handling these interactions in an emergency and they are generally handled informally by requests from PSE to the Bellevue EOC as crews identify needs in the field.

4.2.3.2 Communications with Stakeholders

A major issue during the 2006 winter storm was the lack of communication on the status of the outage and restoration activities. The PSE OMS is currently a manual system as described previously in Section 2.4.6. The system does not currently provide web-based information on specific outage locations and statuses, and the manual process can get overwhelmed in a large outage or emergency.[109] PSE utilizes media outlets to try to communicate during these times; however, this has not been effective in the past at keeping customers at specific locations informed of outage status. Even in a major storm outage (non-emergency), the manual outage management process may be overburdened.

Many utilities are taking lessons learned from major storm events in all parts of the country and are engaging in installation or upgrades to their OMSs. Lessons learned[110] from major storms in

[109] Web-based systems assume that people have access to the Internet, which may not be available during a severe power system outage event.

[110] Reference 35.

the southeast United States indicate the need and the benefits of a fully-integrated computerized system to improve response in major storm events. These integrated systems allow for communication of real-time information to personnel located in multiple locations to facilitate decisions and to update progress. The ability to get visibility into the outage extent and to communicate rapidly with field personnel improves the overall response time. Several other utilities in the Northwest are in the process or have recently upgraded OMSs.

PSE has taken many actions to improve their response to a major event. Some key actions include:

- PSE is currently implementing a major upgrade to its OMS. This upgrade was defined in Section 2.4.6. A key feature of the OMS is that it can automatically locate circuit status visually on a display board that will allow personnel in multiple locations to have access to the data.

- Currently, in a major outage event, where PSE, Bellevue, and King County have activated ECCs and EOCs, communication channels will be strained based on the volume of people needing information. Per their emergency protocols, PSE will communicate from its EOC directly with the King County ECC. The King County ECC communicates with the other governmental entities. Additionally, PSE has liaisons for its various stakeholders and PSE will communicate directly to the City of Bellevue. When completed, the OMS installation should provide a means for faster and more accurate reporting of information.

- The PSE EOC will also issue regular status updates during an emergency. These updates will go to the various EOCs, municipalities, and the news media. The news media (radio) represents a significant distribution channel during major emergency events. PSE also updates its customer call center information to be consistent with releases to the news media. Unfortunately, in a major electric outage, normal communications channels may not be available, and individuals should be equipped with the ability to access the radio news media.

4.2.3.3 Recommendations

The assessment indicates that there are opportunities to improve the communication channel in outage and emergency events. The following recommendations are provided:

- PSE is deploying a new OMS system over the next year that should improve overall outage communications. After deployment, it may be appropriate for selected City personnel involved in emergency response to gain an understanding of the enhanced capabilities in order to better assist in communicating to the Bellevue community.

- There is an opportunity to improve the emergency response and recovery capability between PSE and Bellevue relative to coordination of PSE activities, and Bellevue emergency management, transportation, police, and fire functions. This opportunity may also include Bellevue staff assisting PSE in identifying damaged areas. It is recommended that the City engage PSE in discussions to develop a formal process for these communications to facilitate response and recovery in the future.

- The improvements in the system over the past 5 years have had a positive impact on reducing outages and duration during normal operation. However, the overall system cannot be hardened sufficiently to prevent major outages for an event similar to the 2006 storm. A storm of this magnitude that impacts the regional transmission system requires significant time to restore power to all customers. It is expected that citizens within the City should be prepared to be without power for up to 3–7 days after this type of event. The City should consider an education campaign to make its citizens aware of the problems and help them to be better prepared to deal with future emergencies.

4.3 Role of the City Recommendations

Bellevue's role as an informed stakeholder requires that the City take an active role in becoming informed on matters affecting the reliability and planning for the electric system in Bellevue. This role includes direct communication with PSE as well as other stakeholders regarding electric service. Based on this review, a set of recommendations were described earlier in this section that focus on planning, permitting, emergency or outage management, and regulatory interface. A summary of the assessment is provided below.

Question:

- "What opportunities are available to the City to work with PSE, regulators (WUTC, FERC), and other stakeholders to ensure the needs and expectations of Bellevue's residents and businesses are met relative to the reliability of the power supply?"

Recommendation 1: WUTC Interaction

Finding: From a WUTC perspective relative to electric power, cities are considered as any other member of the public. Bellevue's primary interaction with WUTC is one of being an active participant relative to changes in laws and tariffs that may affect electric system reliability in the state of Washington.

Reliability Actions: Bellevue's ability to be a knowledgeable stakeholder will require assignment of an engineer knowledgeable in the electric power system to foster the City interaction with stakeholders.

Recommendation 1A: Bellevue's involvement with WUTC may be one of informing lawmakers and commissioners of matters that the City believes affect the City's electric reliability or general electric service. For issues affecting electric reliability that are of interest to the City:

- A designated individual can be assigned to electric system matters. The individual should remain informed of electric system activities related to WUTC.
- On matters of interest to the City, white papers can be developed for submittal to WUTC on issues affecting electric reliability. This provides a means to provide feedback to WUTC without direct response to hearings. Potential policy matters could be advanced using this approach.

Recommendation 1B: Bellevue has the opportunity to comment or participate in matters directly affecting PSE and their interaction with WUTC. Bellevue also has the ability to support and advocate for initiatives that meet its goals and objectives. The recommended actions are:

- The City can support or advocate for PSE positions of interest to Bellevue. As programs and rate discussions take place between WUTC and PSE, the City has the opportunity to advocate for positions that support City goals.
- The City should comment and participate in various programs submitted to WUTC by PSE, where PSE is seeking advisory input from stakeholders including the IRP, Smart Grid plan, and reliability programs.

Recommendation 2: Major Project Planning

Finding: The assessment indicates a need to review and update the utility growth plans in the Comprehensive Plan. The large capacity projects will require significant lead time for siting analysis and permitting.

Reliability Actions: Conduct major project discussions well in advance of permit applications to ensure sufficient lead time to permit larger projects (required to add capacity or reinforce the City infrastructure).

Recommendation 2: It is recommended that the City engage PSE in an annual planning workshop around future capacity and expansion projects. The Comprehensive Plan includes an electric system plan that can serve as the basis for the annual workshop. The workshop should focus on the following items:

- Current growth projections and electric power use in Bellevue (see Recommendation Role 3)
- Review of current plan applicability (Figure UT.5a)
- Update of the current plan
- Develop actions for capacity projects required to initiate siting and permitting activities within the next 2 years.

An outcome of the workshop should be an updated plan for inclusion in the Comprehensive Plan (if required), and an action plan to move designated projects forward into siting analysis and/or planning.

As a minimum, the following capacity additions have been identified as being needed within the next 5−10 year time frame:

- Upgrade of the existing 115 kV lines to 230 kV
- Addition of transformer banks to support expected growth in various areas of the City (Downtown, Bel-Red, and Somerset/Eastgate)
- Addition of new 115 kV lines to reinforce the overall electric system.

As previously stated, based on recent Exponent staff experience with T&D capital projects, typical time frames for projects of this size and complexity are as follows:

- Transformer additions require 18−24 months to complete from start of engineering to operation. Additional time is required for planning and permitting.
- Line projects may require 4−5 years from the start of engineering to completion since permitting of lines typically requires significant engineering to be completed before the formal permitting process proceeds.

Recommendation 3: Long-Range Planning

Finding: Both Bellevue and PSE work with various developers and companies to identify new potential facilities in Bellevue. There is an opportunity to share and communicate the results of these planning activities. This exercise relates to longer-term issues that are expected to be addressed in the future.

Reliability Actions: Coordination of Growth Planning and Major Project Activities

Recommendation 3: While information is shared for the IRP, and to the extent that information can be shared, it is recommended that a more formal meeting (annually) be held to ensure that all of Bellevue's needs are identified to PSE and that both organizations are coordinated regarding future load demand. This information sharing can also be included in the annual planning meeting.

The City and PSE should synchronize their growth projections for the City by frequent information exchange on expected projects, expected timing of projects, and coordination actions required by PSE and the City to address these projects. This exchange is meant to assist longer-term planning and should occur well in advance of any specific permitting or development activities.

Recommendation 4: Multi-Utility Planning

Finding: There are opportunities for multiple utilities to take advantage of projects being performed by one of the utilities.

Reliability Actions: This action also represents a potential means to advance undergrounding of circuits if PSE can take advantage of trenching to add conduits for future use.

Recommendation 4A: It is recommended that the City engage their utility partners to identify new projects (both large and small) to attempt to maximize projects in the rights-of-way. This planning activity is intended to take place in advance of permit applications so that the utilities can plan these projects into their annual work.

Recommendation 4B: The City can take advantage of projects that require trenching to place conduit for future use of potential undergrounding. The existence of conduit may allow for more economic alternatives for undergrounding in the future. This action requires City planning to identify future projects that require trenching and to discuss with PSE the placement of conduit. This will be an ongoing action as projects are defined, but can be coordinated through the City Planning Department. (This action is associated with Recommendation Current 3A).

Recommendation 5: Emergency Response Capability

Finding: There is an opportunity to improve the emergency response capability between PSE and Bellevue relative to coordination of PSE activities (e.g., Bellevue transportation, police, and fire functions). Currently, the coordination activities are more informal and on an as-needed basis. This opportunity may also include Bellevue staff assisting PSE in identifying damaged areas.

Reliability Actions: The ability to improve recovery time in Bellevue after an outage can be improved by better coordination between City first responders and PSE crews.

Recommendation 5: The City and PSE should consider the development of a more formal process (procedure) related to response and support activities during an outage. The ability to coordinate activities (especially during a major outage) may include the following activities:

- Locating damage
- Coordination of access to areas of damage
- Access to PSE outage information
- Coordination of recovery plans
- Emergency support to people in need.

The outcome should be an agreement (or procedure) for communication and coordination during large scale events affecting Bellevue.

5 Measurement and Monitoring

5.1 Metrics

The reliability assessment has presented recommendations for the City to consider moving forward. The implementation of these recommendations, if accepted, require metrics to inform the City of the need for action relative to the achieving the goals of the recommendations. Metrics are developed for the set of recommendations to provide the City with a vehicle for tracking progress.

Metrics are typically classified as "lagging" or "leading" metrics. The "lagging" metrics typically include results, such as SAIFI or SAIDI, that indicate performance in the past. "Leading" metrics are those that predict performance in the future. These metrics provide trends that will provide insight into the future results metrics. For example, if maintenance task completions are falling behind schedule, then it can be anticipated that reliability would experience a decline in the future. These "leading" metrics are the type developed for the City. These metrics allow the City to track progress, chart improvement, and guide the need for further corrective action or improvement. These metrics also provide the City with a basis for a meaningful discussion with PSE as an informed stakeholder.

Proposed metrics from the key observation of the reliability assessment are:

- **Performance- and outage-based:**

  There are many metrics that can be reviewed based on information provided by PSE to the City in the Annual Reliability Report, including:

  – Overall City SAIDI and SAIFI (with and without storms since the trends of these outage types provide different information into the health of the system)

  – Circuit level SAIDI and SAIFI (with and without storms similar to above)

  – Equipment failure trends (frequency and duration)

  – Specific trends on circuits that have undergone reliability projects to review improvements gained

  – Review of specific projects targeted for circuits of concern

  Based on the results in this assessment, the following metrics are recommended for the performance- and outage-based findings:

  – There is significant information provided by PSE in the annual reliability report for Bellevue. A metric can be developed that identifies the circuits of concern in Bellevue. This metric is based on the identification of circuits that exceed the PSE system average or the WUTC Service Quality Index for SAIDI and SAIFI. This metric will provide an indication of circuit-level performance in Bellevue.

- A major focus in the study was the performance of the system in the Downtown. A Downtown SAIDI and SAIFI index can be developed for the circuits feeding the Downtown area to monitor reliability there. This measure will provide a focus for identifying the need for additional projects to support reliability in this dense customer area.

- The study identified two causes of outages with very specific solutions. Underground cable failures are a major contributor to outages and there is a program to replace or remediate the cable. Tree-related events are causing overhead conductor failures and a solution offered is the use of covered conductor (tree wire) to reduce outages on a line. Circuits, which have these solutions applied, can be tracked and trended to determine the effectiveness of the solution. These actions are related to preventing outages and the metric is based on the number of outages on these circuits.

- **Design-based:**

  - There is a need to reinforce the looped system in Bellevue by ensuring appropriate redundancy in the system. This redundancy is achieved through the accomplishment of projects to provide back-up feeds to substations and to provide circuit feeder ties that provide additional sources of power. PSE has identified these projects and the metric is to track projects completed to achieve full redundancy in the system.

  - The deployment of automation is identified as a key benefit to managing reliability. There are three specific distribution automation activities that should be tracked to determine the level of automation on the system. The metric is based on tracking percent automation achieved in areas of distribution breaker SCADA and control, sectionalizing switches connected to SCADA, and switch positions reported in SCADA.

- **Growth-based:**

  - There will be a need for additional capacity as Bellevue grows in various areas. The two critical areas for load growth are Downtown and in the Bel-Red area. Since the lead time to permit these additions is expected to be lengthy, it is important for the City to monitor load in these service areas to identify the timing for engaging PSE in discussions prior to the permit application. A measure that monitors the annual load growth will provide the City with a time frame for action. The City can work with PSE to obtain this information and use this in the annual planning workshops.

The specific metrics for these items are included in Table 7. Upon agreement with the City, specific metric plans can be prepared to allow for tracking and trending of these metrics.

Table 7. Proposed Metrics

No.	Metric	Basis	Comment
1	Bellevue Circuits of Concern	Number of Bellevue circuits exceeding PSE system average or WUTC goals for SAIDI and SAIFI. Count of circuits based on information from the Bellevue reliability reports.	The number of circuits exceeding system averages and WUTC goals is a measure of reliability on circuit-level performance and provides trending on reliability.
2	Downtown Reliability	Reliability indices can be created for the Downtown as a whole by aggregating Downtown circuit performance. This measure is based on the SAIDI and SAIFI information from the annual reports and will monitor performance in the Downtown.	Downtown Bellevue has received significant attention in recent years in improving the reliability of the service to the Downtown. This metric is a measure of Downtown performance to identify concerns and possible additional actions.
3	Reliability Project Effectiveness	For circuits with reliability projects for underground replacement/remediation and for overhead installation of tree wire, measure the number of outages on these circuits related to these causes. Count of outages (can be taken from Bellevue reliability report).	Underground cable and tree-related events were identified as major causes of outages in Bellevue. Several actions have been proposed to address these issues. This metric provides a basis for review of effectiveness of reliability actions to prevent outages.
4	System Redundancy	PSE has identified the need to complete redundant feeds into several substations to complete the looped system; and has identified circuits that benefit from installation of switches and feeder ties. Measure of completion of redundancy based on percent of facilities with: • Substations will back-up feed • Circuits with feeder ties/switches	The completion of the looped system as well as reinforcement of circuits provides for greater reliability by improving recovery time and limiting the impacts of outages.
5	Automation Utilization	Measure extent of automation utilization based on percent of facilities with: • Distribution breakers in the substation with SCADA control • Sectionalizing switches connected to SCADA • Switch positions fed to the SCADA system.	This metric measures the extent of automation installation for these items where it is recommended that 100% of the items have automation.
6	Power Demand	Power demand in critical growth areas of the City. Electric power usage in Downtown and Bel-Red (based on information from PSE). Measure of power usage in Downtown and Bel-Red to identify the need to kick-off capacity projects.	Given the long-lead time to install major infrastructure additions within Bellevue, this measure will track growth in the critical growth areas of the City to identify the need to open discussions between Bellevue and PSE and to initiate pre-permitting activities. This should be performed in coordination with the annual planning meeting on potential large projects.

5.2 Stakeholder Communications

The City has many avenues available for communicating with its various constituents regarding the electric reliability initiative. There is significant information available relative to work and status of the electric system reliability. A major concern of the various stakeholders is the timeliness of information on matters that affect the residents and businesses in Bellevue. Relative to issues of electric reliability, outage management, and communications, information can be provided for the following:

- Overall electric performance through the PSE reliability report and various statistical analyses that can be performed by the City around projects and outages in the City. This provides a means to inform and educate the constituents regarding issues affecting electric power.
- Early notification of major growth and projects affecting the City electric system based on planning meetings with PSE.
- Information on electric system outage management and response for both normal and storm conditions that provides a means of emergency preparedness and how to communicate in these circumstances.
- Information relative to identifying critical facilities so that PSE is aware of these prior to emergency events.

This information is mostly available today from the City and PSE in various forms, such as website, downloadable documents, emergency preparedness events, direct mailings, etc. The City has the opportunity to develop a communications plan around electric system performance through the use and publishing of the metrics. The City may choose to combine these with other forms of communication to provide a standard form of update and status. The City of Bellevue website provides a vehicle to communicate to its constituents as an informed stakeholder.

6 Conclusions

The City retained Exponent to perform an electric system reliability assessment to assist the City in meeting its goals to be an informed stakeholder and to work with PSE to ensure a reliable electric power supply for the City. The study was performed to answer the following questions from the Electric Reliability Study Plan[111]:

1. *"How does PSE's existing system serving Bellevue perform relative to WUTC expectations, industry standards, and peers relative to reliability?"*

   There are over 90 circuits in Bellevue and while the performance on individual circuits can vary, the overall system in Bellevue is reliable.

   Electric system reliability is measured by the availability of the system to deliver electric power to a customer's meter in accordance with voltage and frequency requirements specified by WUTC.[112] Reliability is therefore a measure of the probability that electric power is delivered in accordance with those requirements. Electric system reliability is typically measured based on the frequency (SAIFI) and duration (SAIDI) of outages relative to the number of customers.

   WUTC has established reliability goals for its regulated utilities (service quality indices). Prior to 2010, the measures included SAIFI (frequency of outages per customer) and SAIDI (duration of outages per customer) goals for PSE of 1.3 and 136 minutes, respectively, excluding major storm events. While PSE has not always met the SAIDI goals system-wide, Bellevue's reliability has met the SAIFI and SAIDI goals over the past 5 years. In 2010, the reliability in Bellevue measured 0.44 and 66 minutes, respectively for SAIFI and SAIDI. In 2010, the measure for SAIDI was changed to include a 5-year average including major storm events and PSE met that goal system-wide. They will report this measure for Bellevue's circuits in 2011.

   PSE participates in an industry reliability survey through the IEEE. PSE's overall system reliability performance is typically in the 1st or 2nd quartile on SAIFI (frequency of outages) and 2nd or 3rd quartile in SAIDI (duration of outages) (with the 1st quartile being best performance). PSE's 2010 performance for SAIFI and SAIDI was 0.86 and 129 minutes, respectively, and as shown above, Bellevue had significantly better reliability performance.

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111 Reference 10.

112 WAC-480-100.

2. *"What changes relative to facilities, equipment, planning, and emergency operations will improve electric system reliability, communication, and outage response in Bellevue?"*

   While there has been improvement in the reliability of the Bellevue system over the past several years, the following enhancements are required to ensure continued improvement in reliability for the City:

   - Hardening of the Bellevue system to ensure appropriate redundancy to all substations and circuits.
   - Continued focus on underground cable replacement and remediation as well as replacement of older switches and transformers placed in underground vaults.
   - Review of specific circuits within the City that experience lower reliability to identify improvement actions.
   - Accelerate investments in distribution automation (including a DMS, e.g., SCADA) to improve reliability and to enable future technologies.
   - Develop strategies to provide greater opportunities for undergrounding lines experiencing lower reliability due to tree and storm impacts, including review of potential funding mechanisms for overhead to underground conversions and identification of trenching opportunities from other City projects (to include conduit for future use in potential undergrounding).
   - Improvements in the information technology infrastructure for outage management and customer interface to specifically improve communication and outreach to customers during outages on the system.

3. *"Will the City have adequate and reliable power supply to meet future City growth needs?"*

   Based on current plans, the City will have an adequate and reliable power supply to meet the medium-term (5–10 years) and long-term (10–20 years and beyond) growth requirements. The current plan includes:

   - Capacity additions, including upgrade of the 115 kV lines running north-south through Bellevue.
   - Addition of transformer banks to support growth in the Downtown, Bel-Red, and Eastgate/Somerset areas.
   - Upgrade of 115 kV lines to support additional transformer banks.
   - Support of PSE plans to significantly reduce the peak electric power demand through the use of more efficient electric lighting and equipment.

4. *"What opportunities are available to the City to work with PSE, regulators (WUTC, FERC), and other stakeholders to ensure the needs and expectations of Bellevue's residents and businesses are met relative to the reliability of the power supply?"*

   Bellevue's role as an informed stakeholder requires that the City take an active role in becoming informed on matters affecting the reliability and planning for the electric system in Bellevue. This role includes direct communication with PSE as well as other stakeholders regarding electric service. Specific opportunities for the City to engage as an active stakeholder include:

   - WUTC: The City has a role in informing lawmakers and commissioners regarding matters that affect reliability. The City also has the opportunity to comment or participate in matters directly affecting PSE and its interaction with WUTC. It may be possible for Bellevue to support measures for investment brought forward by PSE that support its overall City goals for electric system reliability and service.

   - PSE: The City has many opportunities to proactively interact with PSE on issues related to system reliability, long-term planning, near-term major project planning, Smart Grid initiatives, and emergency planning.

5. *"How can the City measure and monitor whether improvement in reliability is being achieved?"*

   This reliability assessment includes recommendations for the City to consider moving forward. Proposed reliability improvement metrics have also been included to assist the City in measuring and monitoring the implementation and effectiveness of these recommendations.

This reliability study provides the analyses and recommendations to support the City in meeting its goals to be an informed and active stakeholder and to ensure that the City has an adequate and reliable electric system now and into the future.

Appendix A

References

Appendix A. References

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Appendix B

Electric Reliability Basics

Appendix B. Electric Reliability Basics

A discussion of electric system reliability is included here to provide context for the assessment presented in the main text of this report. This background information presents a basic description of the electric system and reliability and provides an explanation of what drives reliability performance. This information is used for reference throughout the report.

B.1. Electric System

The electric system consists of generation, transmission, and distribution systems that deliver power from generation stations to the end user. The overall electric system is depicted in Figure B-1.

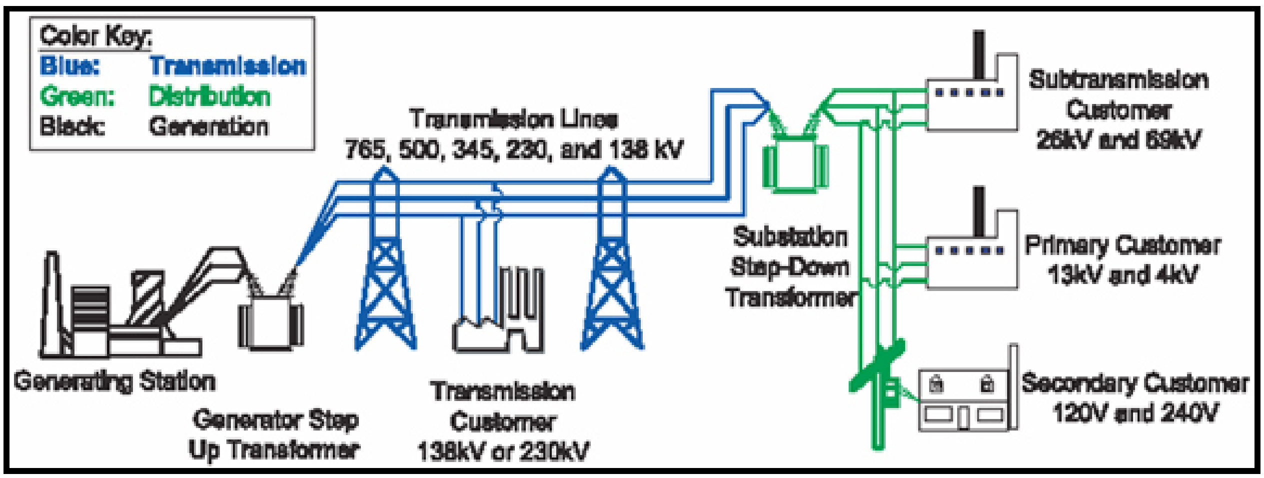

Figure B-1.   Electric Power System

The overall electric power system consists of the following major systems:

- **Generation:** The generation system is made up of large base-loaded power plants (hydro, fossil, nuclear), renewable sources (wind, solar), and smaller distributed generation sources. Generation sources are obtained from utility-owned assets as well as purchased power from third parties. The third-party agreements consist of long-term power contracts, as well as short-term market-based power contracts to meet peak demands. Utilities are required to maintain generation assets with sufficient capacity to meet peak electric power demands and reserve margin requirements. Utilities provide long-term forecasts and plans for generation needs through their integrated resource plans.

- **Transmission:** The transmission system delivers electricity from the generation stations at high voltages to the distribution system. Electricity is stepped up from power plant voltage at the generation station switchyards to transmission level voltages and carried to the substations, which step down voltages to distribution level voltages. The transmission system consists of high voltage lines that typically span long distances from the generation stations to the distributions systems. The high voltage transmission systems are the bulk power supply assets and the transmission system operations affect all utilities connected to the system. Therefore, these transmission systems are monitored and coordinated through regional transmission operators. Transmission systems utilize supervisory control and data acquisition (SCADA) systems and Energy Management Systems to monitor and control the operations of the transmission system and the connected power sources. Also, since the transmission lines carry bulk power affecting large customer populations, they are designed with a high degree of redundancy so that there are multiple sources of power provided to transmission substations that feed the distribution system.

- **Distribution:** The distribution system delivers electricity from the transmission substations to the end users. The end users may be industrial, commercial, or residential users and the utility distribution system typically ends at the customer's meter. The distribution system consists of distribution substations which are fed from the transmission substation that step down voltages to distribution level (typically 12.5kV). The distribution voltage is stepped down to a suitable customer voltage through distribution transformers which are fed from the distribution lines.

These three major systems have varying impacts on electric power delivery reliability.

B.2. Impacts on Reliability

Reliability to the end user is the availability and quality of electric power delivered to their meter. Reliability is impacted by outages on the system that result in a loss of electricity at the meter, as well as variations in voltage characteristics (power quality). While power quality issues are not outages, they may affect the performance of equipment and appliances that are sensitive to voltage fluctuations.

Outages are typically caused by:

- Equipment failures
- Weather-related events (typically wind and storm damage)
- Vegetation-induced faults (e.g., tree branches falling on wires)
- Animal-induced faults (e.g., animal or bird interaction with live components)
- Other types of accidents (e.g., car accidents affecting system assets).

Faults in the electric power system may interrupt delivery of electricity to the end users. A fault produces a disturbance in the electric delivery system that may require the system to shut down for operational and safety reasons. When the fault is identified and corrected, then power delivery can be resumed. This fault identification and correction may be performed by automated systems or by manual intervention. Interruptions on the electric system are classified into several categories:

- Momentary interruptions: These are very short duration outages (industry typically uses less than 1–3 minutes). Power quality occurrences can be categorized as similar to momentary interruptions.
- Sustained interruptions: These are longer duration outages (industry uses greater than 1 – 3 minutes).
- Major interruptions: These are long duration and widespread outages resulting from storms, earthquakes, equipment failures, or other events. These interruptions typically affect a large percentage of the end users.

Relative to measuring reliability, the industry traditionally uses only sustained interruptions in the determination of reliability. However, reporting is often provided for major events or interruptions as a secondary measure. The determination of these reliability measures is discussed later in this section.

The electric system components affect reliability differently. Generation assets are required to be available with sufficient margins that the loss of a power generating facility does not result in outages to end users. For very significant events, such as the northeast outage in 2003, multiple plant shutdowns can result in widespread outages, although these are relatively rare occurrences. Also, if peak electricity demand increases to levels above the generation capacity and reserve margins, then outages can occur. However, for purposes of electric system reliability, generation components do not have a major effect on industry-reported measures of reliability for normal operations.

The transmission system has a very large impact on power delivery and a major event on the transmission system can result in outages for a very large number of customers. However, while a fault or outage of a transmission line or substation has the ability to impact more end users, there are typically sufficient redundancies in transmission assets to minimize the impacts of events on these systems. Additionally, the transmission lines are higher in elevation and usually have larger rights-of-way to reduce the impact of threats to the lines from sources such as trees, animals, and other interactions. Due to these features, transmission assets typically experience far fewer faults than distribution lines; therefore, the transmission system has very little impact on measures of reliability. The ability of the generation and transmission assets to deliver the power demand is more of a longer-term planning concern than a day-to-day reliability concern.

The distribution system directly provides electrical power to customers and is subject to a higher number of faults than generation and transmission assets. Distribution systems are typically designed with less redundancy than the other systems and since this is the system delivering the power to the customers, faults or events on the distribution systems result in outages to customers. Therefore, the potential for local system issues to produce outages is greater than other components in the system. Thus, reliability is primarily governed by distribution system assets.

B.3. Reliability Measures

Today, reliability is typically measured based on the frequency and duration of outages relative to the number of customers. There are several measures for reporting and measuring electric reliability, such as IEEE Standard definitions[113] or similar approaches to report reliability. These measures include SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). These indices are calculated by PSE in their reporting as:

- System Average Interruption Frequency Index (SAIFI)
  - SAIFI = (Sum of the number of customers affected by each outage) divided by (Total number of customers served)
- System Average Interruption Duration Index (SAIDI)
  - SAIDI = (Sum of the number of customers interrupted times the number of minutes of each interruption) divided by (Total number of customers served).

These measures are based on the customer base served. SAIFI measures the number of outages that a customer experiences and SAIDI measures the outage duration (minutes) that a customer experiences. Therefore, these measures represent the average number and duration of outages experienced per customer. These measures provide a basis for tracking and trending overall performance and allow for comparison among utilities.

Momentary interruptions (and power quality excursions) are typically not measured or monitored continuously at end user sites and are not included in the reliability calculations. Currently, most utilities do not actively track these momentary outages, but work with customers directly to address them when these issues are identified as problems. Customer sites that are very sensitive to momentary or power quality issues typically develop site-specific solutions to protect their assets and operations.

Additionally, major outages are typically not included in reliability measures since these major outages are not representative of how the electric system normally performs. However, utilities today are providing additional reliability measures that include major outage effects. While these reliability measures allow for tracking and trending performance, they also provide a basis

[113] Reference 11.

for how an electric utility responds to these measures.[114] Utilities use these reliability statistics to identify problem areas and define actions to improve reliability.

B.4. Reliability Drivers

Since the reliability of the electric system is measured by metrics similar to SAIDI and SAIFI, a key to understanding reliability is defining what factors affect reliability. Electric system reliability relative to the frequency or occurrence of outages is impacted by the following:

- **System Design (Layout):** Distribution system designs vary in the extent of system redundancy (a high level of redundancy means that the system can withstand more contingencies without affecting the customers). In more urban areas, the distribution system may consist of a network that is a highly redundant and allows electricity to be provided from multiple sources (substations). Therefore, a fault on one line may not result in interruptions, since electricity is available from multiple sources. In more rural or less populated areas, the distribution system may be radial. A radial system has limited or little redundancy. A fault on the line will result in an outage of some type. There is only one source (substation) feeding a radial line. Additionally, there are system designs that lie somewhere in between a network and a radial system. Therefore, the overall system design impacts the response of the system to faults and has an impact on the number and duration of outages. System design solutions typically involve additions, modifications, or expansions to the existing system to improve reliability through design. These solutions affect both the occurrence and duration of outages.

- **System Design (Operations):** The degree of automation built into the system has a major impact on reliability. Devices that allow faults to be cleared automatically result in quick power restoration to those not affected by the fault. Also, the degree of automation allows for better knowledge of system status, faster identification of fault locations, and the ability to remotely restore power. Limited automation requires personnel to travel to the fault location and to take manual action to restore power to those who are affected by the fault. Therefore, system operations (and automation) have a significant impact on the number of sustained outages and the duration of outages.

- **Equipment Maintenance and Replacement Programs:** Many outages are produced by equipment failures. Typically, substation equipment failures result in outages which affect more end users since the substations feed multiple circuits. However, looped radial feeds from other substations to distribution circuits, which is the typical circuit topology for most of PSE's Bellevue distribution system, helps limit outage time to that required to disconnect faulty circuit elements and connect

[114] For example, restoration of power to most of the customers reduces the duration and number of customers affected by an outage more than a long duration outage to a few customers. Since there are financial penalties associated with not meeting the reliability targets to many utilities, restoring power to as many users as possible with a minimum of delay reduces the penalties.

the alternate feed(s). Substation equipment is typically subject to preventive or predictive maintenance to reduce the potential failure of components that impact substation performance. Also, key substation assets are being equipped with continuous monitoring technologies that allow for identification of problems prior to equipment failure. Distribution line equipment is most likely to include maintenance strategies that also consider run-to-failure. Distribution circuits affect a lower number of customers. The distribution assets are typically low-cost and easy to replace items and are traditionally replaced on a set time frame. However, utilities modify their maintenance strategies and programs to direct improvements in parts of the system experiencing higher levels (frequency and duration) of outages.

- **Capital Project Prioritization Programs:** The capital project program includes projects that are capacity expansions, system configuration changes, major equipment replacements, system upgrades, reliability programs, and technology upgrades. The priority of capital projects focusing on system reliability is a major factor in improving reliability. Utility planners review overall system impacts for new and existing infrastructure and projects are selected and budgeted. The ability to trend and analyze outages provides a basis for defining projects and programs and these capital programs have a direct impact on system reliability through minimizing outages.

- **Vegetation Management:** A significant number of faults (and outages) on the overhead distribution system are caused by tree-related events. Utilities conduct tree trimming and vegetation management programs to minimize the impact of faults due to vegetation impacts on power lines. Since this is a primary cause of faults, the effectiveness of the vegetation management program is a key to improved reliability.

- **Animal Abatement:** Similar to vegetation management, utilities conduct animal abatement programs to minimize the potential for outages produced by birds, squirrels, and other animals.

- **Outage Management Programs:** The ability to respond to an outage directly impacts the reliability of the system relative to duration of outages. Keys to effective outage management are the ability to quickly identify outages and to locate faults so that appropriate restoration actions can be taken. The outage management program includes operational visibility into the system, the ability to dispatch crews to fault locations, and the ability to effectively communicate with customers. Overhead line faults might be cleared by automatic reclosing, but underground faults are typically permanent faults that require people to diagnose the problems. Also, many times the fault location has to be inspected before power can be restored.

These work processes are the primary activities that utilities perform to improve overall system reliability.

Appendix C

Outage and Equipment Codes

Appendix C. Outage and Equipment Codes

Table C-1.   Outage Cause Codes

Code	Description
AO	Accident Other, with Fires
BA	Bird/Animal
CP	Car-Pole Accident
DU	Dig Up–Underground
EF	Equipment Failure
EO	Electrical Overload
FI	Faulty Installation
LI	Lightning
MW	Manufacturer/Workmanship
NYD	Not Yet Determined–Substation
OE	Operating Error
PO	Partial Outage
TF	Tree Off Right-of-way
TO	Tree On Right-of-way
UN/UU	Unknown Cause
VA	Vandalism

The outage codes utilized in the report are based on a simplified list of codes:

- Equipment failure (EF), which includes code EF only
- Trees and vegetation (T&V), which includes codes TF and TO
- Bird and animal (BA), which includes code BA only
- External accidents (ACC), which includes codes, AO, CP, DU, and VA
- Operations (OPS), which includes EO, OE, and PO
- Other (OTH), which includes FI, LI, MW, NYD, and UN/UU.

Table C-2. Equipment Codes

Code	Description	Code	Description	Code	Description
ACE	All Customer Equipment	OPS	Overhead Pole Stub	UFE	Underground Fused Elbow
CDH	Conductor Down and Hot	ORE	Overhead Regulator	UFI	Underground Fault Indicator
CFD	Capacitor Bank Fuse Disconnect	OSL	Overhead Street Light	UFJ	Underground J-box
CTX	Transformer Instrument (current)	OSP	Overhead Splice	UFO	Underground Fiber Optics
DNO	Did Not Operate	OSS	Overhead School Signal	UFS	Underground Fire Signal
OAL	Overhead Area Light	OST	Overhead Step Transformer	UGF	Underground Submersible Fuse
OAN	Overhead Anchor	OSV	Overhead Service	UGV	Underground Vault
OAR	Overhead Arrestor	OSW	Overhead Switch	UHH	Underground Handhole (secondary)
OAT	Overhead Auto Transformer	OTF	Overhead Transformer Fuse	UHM	Underground Hammerheads (splices)
OCA	Overhead Capacitor	OTH	Other	UIC	Underground Indoor Stress Cone
OCE	Overhead Customer Equipment	OTR	Overhead Transformer	UJU	Underground Primary Jumper
OCN	Overhead Connector	OTS	Overhead Traffic Control Signal	UMP	Underground Submersible Meter Point
OCO	Overhead Conductor	OUP	Overhead to Underground Primary	UNK	Unknown
OCR	Overhead Crossarm	OUS	Overhead to Underground Secondary/Service	UOT	Underground Outdoor Termination
OFC	Overhead Cut-out	PED	Pedestal (secondary)	UPC	Underground Primary Cable
OFI	Overhead Fault Indicator	PFT	Padmount Fast Transformer	UPH	Underground Padmount Phase Shifter
OFL	Overhead Flood Light	PMF	Padmount Switch Fuse	UPS	Underground Padmount Switch
OFS	Overhead Fire Signal	PMJ	Padmount J-box	UPT	Underground Padmount Transformer
OFU	Overhead Line Fuse/ Fuse Link	PMP	Padmount Meter Point	USC	Underground Secondary Cable
OGD	Overhead Down Guy	PST	Padmount Step Transformer	USE	Underground Secondary Connection

Table C-2. (cont.)

Code	Description	Code	Description	Code	Description
OGS	Overhead Span Guy	PTF	Padmount Transformer Fuse	USP	Underground Primary Splice
OHR	Overhead Recloser	SBF	Substation High Side Bank Fuse	USS	Underground School Signal
OHS	Overhead Sectionalizer	SCB	Substation Power Circuit Breaker	USV	Underground Service
OIN	Overhead Insulator	SCS	Substation Circuit Switcher	UTC	Underground Terminal Fuse
OJU	Overhead Jumper Wire	SPT	Substation Station Power Transformer	UTF	Underground Submersible Transformer Fuse
OMP	Overhead Meter Point	SRG	Substation Station Regulator	UTR	Underground Submersible Transformer
ONI	Overhead Neutral Isolator	UCU	Underground Copper Communications Cable	UTS	Underground Traffic Control Signal
OPB	Overhead Pole	UDC	Underground Dust Cap	UUS	Underground Submersible Switch
OPI	Overhead Insulator Pin	UEL	Underground Elbow	XFR	Transformer Unknown Type
OPO	Overhead Pole	UFE	Underground Fused Elbow		

Appendix D

List of Documents Reviewed

Appendix D. List of Documents Reviewed

City of Bellevue Documents

1. City of Bellevue City Council's Electric Reliability Interest Statement, July 2008
2. City of Bellevue Comprehensive Plan, Utilities Element
3. Franchise Agreement between Bellevue and PSE, Ordinance No. 5443, May 2003.

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4. PSE SQI and Electric Service Reliability Report, 2010 Annual Report, Filed with WUTC March 31, 2011.
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24. Washington Administrative Code (WAC) 480-100 Electric Companies
25. Washington Administrative Code (WAC) 480-107 Purchase of Electricity from Qualifying Facilities and Independent Power Producers
26. Washington Administrative Code (WAC) 480-108 Interconnection with Electric Generators
27. Washington Administrative Code (WAC) 480-109 Acquisition of Minimum Quantities of Conservation and Renewable Energy
28. Washington Utilities and Transportation Commission Session Rulemaking Electric Vehicles Regulation and Infrastructure (UE-101521/UE-101800)
29. Washington Utilities and Transportation Commission Rulemaking on Smart Grid Reporting (U-090222)

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37. PSE Electric Relay Work Practice Standards
38. PSE Presentations and Reviews on the Following Topics:
    a. Current Customer Service and Outage Management System (CLX)
    b. Future GIS/OMS/DMS
    c. Current Operations Center
    d. Distribution System Design, Loadings, and Operations
    e. Transmission System Design, Loadings, and Operations
    f. Capital Project Planning and Prioritization
    g. Projects and Reliability Initiatives in Bellevue
    h. Substation and Line Maintenance and Problem Investigations
    i. Emergency Planning
    j. Substation and Line Visual Inspections

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61. J.D. Power and Associates 2010 Electric Utility Customer Satisfaction Study

Appendix E

Circuit Reliability Analysis

Appendix E. Circuit Reliability Analysis

This appendix provides an assessment of circuit reliability to assist in identifying representative circuits for analysis within Bellevue. The figure below (a copy of Figure 32 in the body of the report) provides the location of substations within Bellevue. The table that follows provides the basis for the circuit selection.

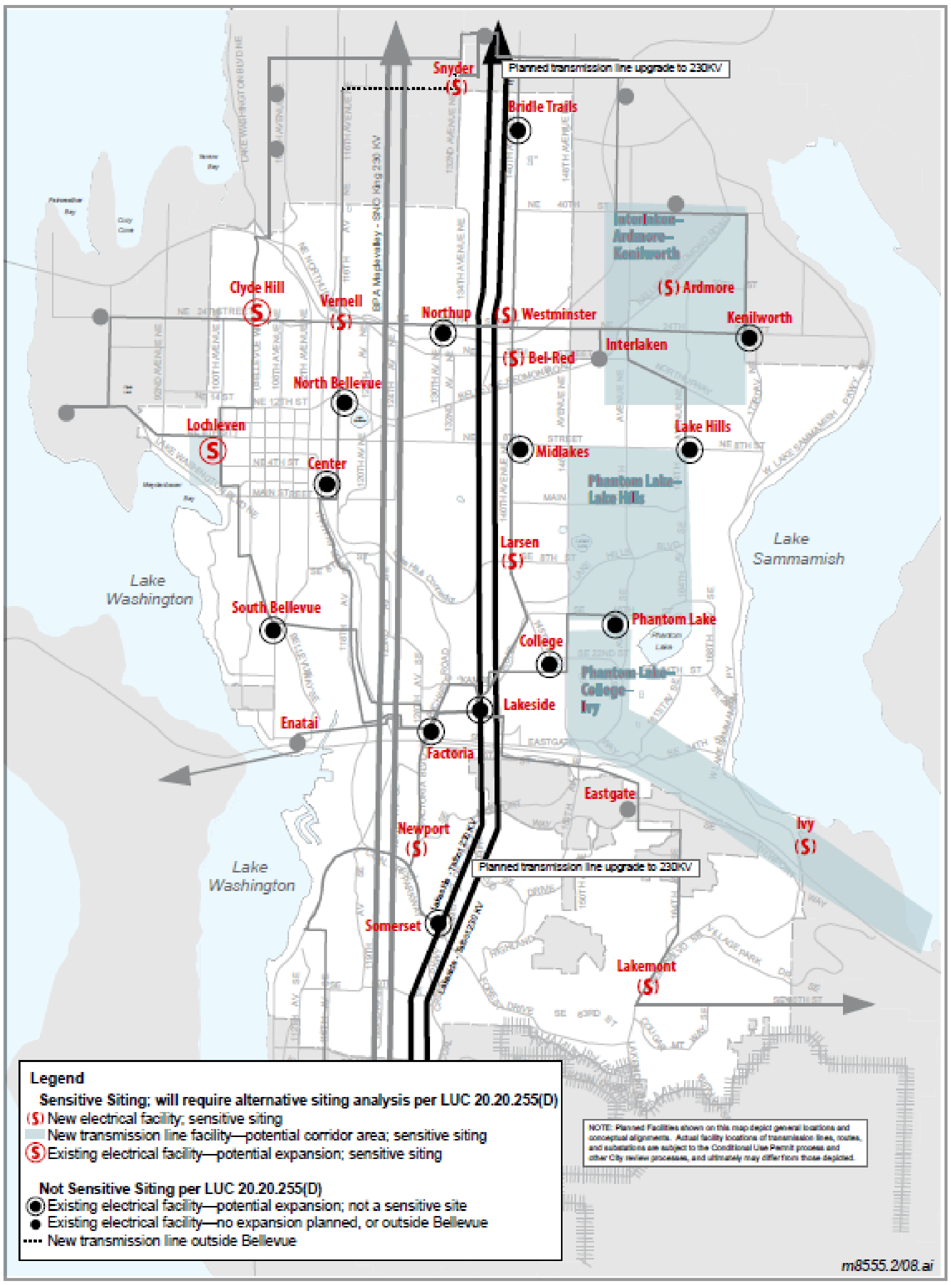

FIGURE UT.5a

New or Expanded Electrical Facilities

Appendix E. Circuit Reliability Analysis

			2010		2009		2008		2007		2006					
CIRCUIT NAME	CIRCUIT NO.	No. of Customers (2010)	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	Total Minutes	Circuit SAIDI	Total Outages	Note
Bridal Trails	BTR-24		0	0	0	0	0	0	0	0	2	21,756	21,756		2	N.A.
Somerset	SOM-01		0	0	0	0	0	0	1	600,710	0	0	600,710		1	Captured multi-circuit event
Factoria	FAC-16	2	0	0	5	359,838	10	57,441	8	73,813	11	46,861	537,953		34	Limited customers
Somerset	SOM-16	1,274	4	142,436	5	18,111	11	2,193,687	13	309,921	10	239,244	2,903,399	456	43	SOM-16 has higher value, but single event caused most of the minutes in 2008. Therefore, SOM-13 selected based on past 2 years.
Factoria	FAC-15	7	0	0	0	0	1	11,804	0	0	0	0	11,804	337	1	Limited customers
Northrup	NRU-23	461	4	12,167	16	73,819	14	404,614	9	34,991	16	98,620	624,211	271	59	Highest NRU circuit and indicated as impacted in 2006
Center	CEN-15	213	0	0	0	0	2	1,243	3	149,017	5	124,772	275,032	258	10	Downtown circuit
South Bellevue	SBE-22	300	2	15,462	3	4,145	8	327,115	2	405	5	8,796	355,923	237	20	Other SBE circuits have higher values, but SBE-26 had a large number of outages and has a high population.
Bridal Trails	BTR-22	647	8	37,473	10	39,768	17	360,574	6	8,258	18	242,977	689,050	213	59	Highest BTR circuit and indicated as impacted in 2006
College	COL-24	20	0	0	2	16,933	0	0	1	2,203	0	0	19,136	191	3	Limited customers
Northrup	NRU-27	660	9	11,538	7	29,526	9	174,612	7	108,996	6	193,100	517,772	157	38	NRU-23 selected
College	COL-26	1,720	6	34,364	11	70,324	13	643,970	15	147,856	18	360,836	1,257,350	146	63	Low numbers last two years
Lochleven (incl. LLOC-25,26,27 in 2005, 2006)	LOC-34	188	1	426	1	995	1	7,875	0	0	8	114,808	124,104	132	11	Downtown circuit
Somerset	SOM-13	1,026	7	375,903	8	129,848	5	785	6	29,982	9	95,343	631,861	123	35	SOM-16 has higher value, but single event caused most of the minutes in 2008. Therefore, SOM-13 selected based on past 2 years.
Phantom Lake	PHA-16	1,954	9	249,092	13	32,893	16	316,522	14	303,861	14	299,979	1,202,347	123	66	Selected LHL-23
South Bellevue	SBE-23	246	1	9,090	2	5,430	3	112,719	4	9,663	5	12,152	149,054	121	15	Other SBE circuits have higher values, but SBE-26 had a large number of outages and has a high population.
Lake Hills	LHL-25	2,811	12	113,322	14	231,746	12	191,648	15	923,174	12	195,276	1,655,166	118	65	LHL-25 and LHL-23 have comparable numbers. LHL-23 selected based on high duration per outage.
Northrup	NRU-26	173	2	1,086	2	794	5	23,375	2	10,117	7	64,760	100,132	116	18	NRU-23 selected
Somerset	SOM-15	1,828	14	76,707	14	103,766	16	578,736	12	58,653	12	212,663	1,030,525	113	68	SOM-16 selected
Medina	MED-36	736	8	93,388	11	36,318	11	42,407	7	37,203	14	196,125	405,441	110	51	Partial circuit in Bellevue
South Bellevue	SBE-25	1,317	8	72,311	10	20,869	9	517,946	8	31,382	6	76,750	719,258	109	41	Other SBE circuits have higher values, but SBE-26 had a large number of outages and has a high population.
Lake Hills	LHL-23	1,497	3	299,300	3	50,909	3	382,965	5	43,627	3	19,603	796,404	106	17	LHL-25 and LHL-23 have comparable numbers. LHL-23 selected based on high duration per outage. LHL circuit also selected since this is a radial circuit.
Clyde Hill	CLY-23	608	11	75,397	8	59,825	14	142,412	6	9,441	12	26,228	313,303	103	51	
Overlake	OVE-15	543	16	15,571	11	169,231	13	74,801	12	8,342	9	9,249	277,194	102	61	
South Bellevue	SBE-26	1,742	15	143,380	19	52,110	31	463,939	30	59,716	34	158,342	877,487	101	129	Other SBE circuits have higher values, but SBE-26 had a large number of outages and has a high population.
Kenilworth	KWH-25	1,959	20	183,308	26	103,260	0	0	24	177,823	34	509,679	974,070	99	104	
Lochleven	LOC-23	2,170	6	140,036	12	28,096	10	267,667	11	37,448	14	588,762	1,062,009	98	53	
Phantom Lake	PHA-13	1,041	13	157,821	13	50,137	16	16,923	8	31,572	11	211,838	468,291	90	61	
Northrup	NRU-14	156	1	23,480	0	0	0	0	1	207	2	45,860	69,547	89	4	
North Bellevue	NOB-23	375	2	24,826	3	68,607	0	0	3	18,373	6	53,122	164,928	88	14	
Midlakes	MLK-15	977	5	50,819	5	244,115	5	97,933	4	33,883	3	1,893	428,643	88	22	
Lake Hills	LHL-22	1,085	4	10,066	7	2,566	13	449,802	9	9,513	5	959	472,906	87	38	
Evergreen	EVE-23	2,561	10	35,032	0	0	0	0	28	660,667	19	419,006	1,114,705	87	57	
Bridal Trails	BTR-21	1,307	8	17,107	5	126,317	22	248,988	8	82,606	8	70,877	545,895	84	51	
Eastgate	EGT-11	1,177	6	81,361	11	194,631	10	21,381	8	66,565	15	115,433	479,371	81	50	
North Bellevue	NOB-13	32	1	79	2	12,844	0	0	0	0	0	0	12,923	81	3	

Appendix E. Circuit Reliability Analysis (cont.)

			2010		2009		2008		2007		2006					
CIRCUIT NAME	CIRCUIT NO.	No. of Customers (2010)	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	Total Minutes	Circuit SAIDI	Total Outages	Note
Eastgate	EGT-12	2,599	27	39,368	23	449,090	21	245,206	13	20,371	14	276,514	1,030,549	79	98	
Midlakes	MLK-16	1,733	6	10,180	7	70,043	9	408,764	7	89,954	11	100,725	679,666	78	40	
Eastgate	EGT-28	1,585	11	180,150	9	182,759	14	101,861	17	52,890	16	84,960	602,620	76	67	
Interlaken	INT-15	776	2	69,168	2	31,405	2	62,063	3	13,469	1	115,946	292,051	75	10	
North Bellevue	NOB-11	193	1	1,983	1	31,965	2	17,386	3	5,096	6	15,821	72,251	75	13	
Eastgate	EGT-16	465	7	14,854	5	6,390	3	79,129	8	5,728	13	61,300	167,401	72	36	
Eastgate	EGT-15	351	3	99,883	3	7,942	3	8,524	4	3,689	4	5,569	125,607	72	17	
Northrup	NRU-25	903	10	6,274	6	6,348	10	57,619	8	62,114	13	185,200	317,555	70	47	
Eastgate	EGT-25	754	6	14,104	5	174,164	11	8,725	9	27,627	6	34,218	258,838	69	37	
Clyde Hill	CLY-27	703	4	8,936	5	100,215	8	31,654	5	12,133	7	74,342	227,280	65	29	
Lake Hills	LHL-26	507	6	86,110	3	34,885	1	2,643	3	30,718	5	3,296	157,652	62	18	
Midlakes	MLK-12	427	2	52,454	5	4,963	3	11,561	8	42,490	5	19,947	131,415	62	23	
Hazelwood	HAZ-12	2,126	12	9,985	9	6,026	15	24,529	22	336,247	14	260,626	637,413	60	72	
Interlaken	INT-17	428	1	45,475	4	26,380	0	0	3	38,530	3	17,799	128,184	60	11	
College	COL-25	446	1	5,186	0	0	2	13,064	3	90,877	4	21,403	130,530	59	10	
Clyde Hill	CLY-26	818	9	32,241	6	44,079	11	57,326	9	70,625	9	31,144	235,415	58	44	
College	COL-23	489	1	1,728	3	6,882	4	60,431	1	10,736	3	52,149	131,926	54	12	
Kenilworth	KWH-22	640	4	10,759	5	4,191	10	146,814	5	2,956	9	3,805	168,525	53	33	
Bridal Trails	BTR-14	1,140	0	0	3	290,540	0	0	0	0	0	0	290,540	51	3	
North Bellevue	NOB-12	471	0	0	3	112,053	0	0	0	0	2	5,782	117,835	50	5	
Hazelwood	HAZ-13	1,117	9	20,401	7	4,675	9	10,426	11	70,709	13	158,472	264,683	47	49	
Somerset	SOM-17	1,749	2	3,695	13	149,457	22	39,796	2	1,330	23	194,709	388,987	44	62	
Kenilworth	KWH-23	665	5	39,092	9	22,232	4	33,782	4	2,745	7	49,230	147,081	44	29	
Factoria	FAC-13	1,568	12	50,677	18	98,635	17	79,713	23	47,143	26	66,336	342,504	44	96	
Eastgate	EGT-27	685	8	12,059	11	19,783	12	17,484	11	12,588	7	79,222	141,136	41	49	
Overlake	OVE-12	674	10	6,989	12	21,804	10	2,714	12	94,513	12	10,700	136,720	41	56	
Bridal Trails	BTR-25	1,130	5	39,700	0	0	2	5,378	1	9,472	5	165,364	219,914	39	13	
Center	CEN-11	5	0	0	1	969	0	0	0	0	0	0	969	39	1	
Midlakes	MLK-13	1,278	5	13,599	5	48,919	6	31,240	11	43,582	9	87,461	224,801	35	36	
Kenilworth	KWH-26	276	1	5,696	1	171	0	0	5	22,454	2	16,312	44,633	32	9	
Center	CEN-14	654	0	0	1	290	5	39,177	1	35,000	1	29,175	103,642	32	8	
Eastgate	EGT-26	115	1	14,532	1	175	1	274	1	485	1	1,325	16,791	29	5	
Bridal Trails	BTR-23	512	0	0	0	0	0	0	3	60,277	3	9,235	69,512	27	6	
Goodes Corner	GOO-13	1,745	0	0	0	0	0	0	3	118,968	4	93,911	212,879	24	7	
Phantom Lake	PHA-17	644	4	4,778	10	16,252	6	18,307	9	24,274	5	11,304	74,915	23	34	
North Bellevue	NOB-22	35	0	0	0	0	0	0	0	0	3	3,933	3,933	22	3	
Phantom Lake	PHA-15	176	0	0	2	1,901	6	16,768	2	271	3	654	19,594	22	13	
North Bellevue	NOB-24	1,080	5	8,113	8	33,240	9	34,138	11	12,604	6	31,320	119,415	22	39	
Clyde Hill	CLY-25	2,020	7	29,665	5	28,025	4	12,497	6	12,544	6	120,672	203,403	20	28	
North Bellevue	NOB-14	276	0	0	1	24,562	0	0	0	0	1	190	24,752	18	2	
Lochleven	LOC-35	187	1	169	3	15,481	0	0	1	79	0	0	15,729	17	5	
Center	CEN-25	483	2	10,708	3	27,106	0	0	0	0	0	0	37,814	16	5	
Houghton	HOU-25	485	0	0	0	0	0	0	2	1,167	6	35,966	37,133	15	8	
Center	CEN-12	182	1	11,486	0	0	0	0	0	0	0	0	11,486	13	1	
Factoria	FAC-24	89	3	4,916	0	0	0	0	0	0	0	0	4,916	11	3	
Factoria	FAC-14	287	1	8,011	0	0	0	0	0	0	0	0	8,011	6	1	
Lochleven	LOC-33	363	2	364	2	7,949	0	0	1	1,428	0	0	9,741	5	5	
North Bellevue	NOB-21	519	0	0	2	1,397	1	1,679	3	3,177	3	3,845	10,098	4	9	
Factoria	FAC-12	1,190	8	16,275	1	231	1	403	0	0	1	438	17,347	3	11	
Factoria	FAC-23	78	1	900	0	0	0	0	0	0	0	0	900	2	1	

Appendix E. Circuit Reliability Analysis (cont.)

			2010		2009		2008		2007		2006					
CIRCUIT NAME	CIRCUIT NO.	No. of Customers (2010)	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	OUTAGES	CUSTOMER MINUTES	Total Minutes	Circuit SAIDI	Total Outages	Note
Factoria	FAC-25	1,331	9	10,659	1	80	0	0	0	0	0	0	10,739	2	10	
Clyde Hill	CLY-22	245	0	0	1	1,430	0	0	0	0	0	0	1,430	1	1	
Overlake	OVE-13	301	1	160	0	0	0	0	0	0	0	0	160	0	1	
Center	CEN-13	5	0	0	0	0	0	0	0	0	0	0	0	0	0	
Center	CEN-22	6	0	0	0	0	0	0	0	0	0	0	0	0	0	
College	COL-22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
Eastgate	EGT-13	7	0	0	0	0	0	0	0	0	0	0	0	0	0	
Factoria	FAC-21	79	0	0	0	0	0	0	0	0	0	0	0	0	0	
Lochleven	LOC-22	176	0	0	0	0	0	0	0	0	0	0	0	0	0	
Lochleven	LOC-24	15	0	0	0	0	0	0	0	0	0	0	0	0	0	
Lochleven	LOC-25	245	0	0	0	0	0	0	0	0	0	0	0	0	0	

Notes:

1. This table provides an analysis of circuits for selection as representative circuits for the outage assessment.
2. Circuit SAIDI approximated by the summation of outage duration over the past 5 years divided by the number of customers (2010 basis) and averaged over 5 years. The circuits were then ranked by circuit SAIDI.
3. Total number of outages over the 5 years was also determined to add insight into the selection process.
4. The circuits were then reviewed to select circuits that represented different geographic areas of Bellevue.
5. The circuits in specific areas were reviewed for number of customers to ensure that appropriate customer representation was considered.
6. Circuits selected for representative circuit review are highlighted and explanation provided under “notes”.

Appendix F

Reliability Projects in Bellevue

Appendix F. Reliability Projects in Bellevue

PSE performs a significant number of capital projects around their service area each year. These projects typically include capital replacement (equipment replaced at the end of its useful life), capital improvement (expansion, operations flexibility, system hardening), and reliability (projects aimed at reliability improvements). During discussions with PSE, they indicated the following projects in Bellevue were directly targeted at reliability in the City. Most capital projects will have an indirect benefit on reliability, but the list below is targeted at improved system reliability. The reliability projects are designated as supporting the Downtown if the project has an impact on the Downtown area in Bellevue.

Year	Location	Project
2007	CEN	CEN-1N reconfiguration (Downtown circuit)
2007		Install service (Downtown)
2007	LOC	LOC-21 (2N) reconfiguration (Downtown circuit)
2007	CEN	CEN-2N feeder project (Downtown)
2007	COL	COL-25 BO getaways
2007	LOC	LOC-3N feeder project (Downtown)
2008		1/0 loop (Downtown)
2008	KWH	KWH-25 tree wire installation
2008	LHL	LHL-25 underground rebuild
2008	CEN	CEN-12 reconfiguration (Downtown)
2009	NOB	NOB-21 feeder (Downtown)
2009	LOC	LOC-25 feeder (Downtown)
2009	CEN	CEN-14 1/0 cable reliability (Downtown)
2009	CLY	CLY-26 install Vista switch (Downtown)
2009	NOB	NOB-13 install Vista switch (Downtown)
2009	SOM/EGT	SOM-13/EGT-12 underground feeder tie
2009	GOO/EGT	GOO-13/EGT-12 underground feeder tie
2009	NOB	NOB-12 underground feeder re-route (Downtown)
2009	CLY	CLY-26 install underground feeder (Downtown)
2009	CLY	CLY-25 install underground feeder (Downtown)
2009	FAC	FAC-14 replace conduit and feeder
2010	CEN	CEN-14 circuit re-route (Downtown)
2010	LOC	LOC-34 Bellevue Square rebuild (Downtown)
2010		Install FI with remote communication (Downtown)
2010		Replace failed recloser
2010	CLY	CLY-25/CLY-26 install feeder tie (Downtown)
2010	SOM	SOM-13 reliability project add PM switch

Year	Location	Project
2010	CEN	CEN-14 underground reliability project
2010	EGT/COL	EGT-13/COL-24 feeder tie
2010	LOC	LOC-23 underground feeder project (Downtown)
2010	CLY	CLY-2N reliability circuit (Downtown)
2010	NOB	NOB-22 underground feeder reconfiguration (Downtown)
2010	CEN	CEN-25 feeder extension
2010	EGT	EGT-28 feeder tree wire reconductor
2010	NRU	NRU-23 feeder tree wire
2010	PHA	PHA-16 remove switch
2010	NRU	NRU-23 underground conversion of feeder
2010	NRU	NRU-26 replace switch
2011	PHA	PHA-13, 16 & 17 underground feeder rebuild
2011	CLY	CLY-23 1/0 cable replacement

Appendix G

Phase 1 vs. Phase 2 Roadmap

Appendix G. Phase 1 vs. Phase 2 Roadmap

The table below provides a roadmap for indexing the Phase 1 tasks against the results presented in this reliability study.

Phase 1 Report		Phase 2 Report	
Section	Topic	Section	Topic
2.1 Task 1	Current System Study	2	Current System Assessment
Subtask 1.1	Review of PSE Performance	2.2	PSE Past and Present Reliability and Outage Performance
Subtask 1.2	Review of PSE System Design	2.3	Review of PSE's System Design
Subtask 1.2.a	Washington Requirements	2.3.3	Washington Requirements
Subtask 1.2.b	Power Supply	2.3.4	Power Supply
Subtask 1.2.c	Transmission Planning	2.3.5, 2.3.6	Bulk Transmission/115 kV System
Subtask 1.2.d	Distribution Planning	2.3.7	Distribution System
Subtask 1.3	Review of PSE Line and Station Design and Maintenance Practices	2.3.8, 2.4	Substation Designs/Work Practices
Subtask 1.4	Industry Benchmarks	2	Included throughout Section 2
2.2 Task 2	Future System Assessment	3	Future System Assessment
Subtask 2.1	Short Term	2.3	System Design
Subtask 2.1.a	Capital Project Investments	2.3.4/2.3.5	Power Supply/Transmission
Subtask 2.1.b	Short-Term Supply and Demand	2.3.4/2.3.5	Power Supply/Transmission
Subtask 2.1.c	Life Extension	2.2.6	Industry Issues
Subtask 2.1.d	WUTC Expectations	2.3.3	Regulatory Agencies
Subtask 2.1.e	Smart Grid Deployment	3.2.5	Smart Grid Technology
Subtask 2.1.f	Outage Management and Other Operating Systems	2.4.6.5/4.2.3.1	Outage Management/Emergency Management
Subtask 2.2	Medium Term	3.2	Medium Term
Subtask 2.2.a	Retirement of Power Agreements	3.2.2	Generation 3.3
Subtask 2.2.b	New Power Sources	3.2.2	Generation
Subtask 2.2.c	New Transmission	3.2.3	Transmission
Subtask 2.2.d	Distribution	3.2.5	Distribution
Subtask 2.3	Long Term	3.3	Long Term
Subtask 2.2.a	Risk Analysis	3.3.4	New Power Sources
Subtask 2.2.b	Transmission	3.3.2	Transmission
Subtask 2.2.c	Fully Built-Up Downtown	3.3.5	Fully Built-Out Downtown
Subtask 2.2.d	Distribution	3.3.5	Fully Built-Out Downtown
2.3 Task 3	Role of the City	4	Role of the City
Subtask 3.1	Role as Informed Stakeholder	4.2	Role as Informed Stakeholder

Phase 1 Report		Phase 2 Report	
Section	Topic	Section	Topic
Subtask 3.1.a	WUTC	4.2.1	Regulatory Agencies
Subtask 3.1.b	PSE	4.2.2	PSE
Subtask 3.1.c	Regulatory Agencies	4.2.1	Regulatory Agencies
Subtask 3.2	Transparency	4.2.3	Transparency of Operations
Subtask 3.2.a	Define	4.2.3	Transparency of Operations
Subtask 3.2.b	Emergency Plan	4.2.3.1	Emergency Planning
Subtask 3.2.c	Communications	4.2.3.2	Communications with Stakeholders
2.4 Task 4	Measure and Monitor	5	Measurement and Monitoring
Subtask 4.1	Metrics	5.1	Metrics
Subtask 4.2	Stakeholder Communication	5.2	Stakeholder Communication

Appendix H

Response to Questions